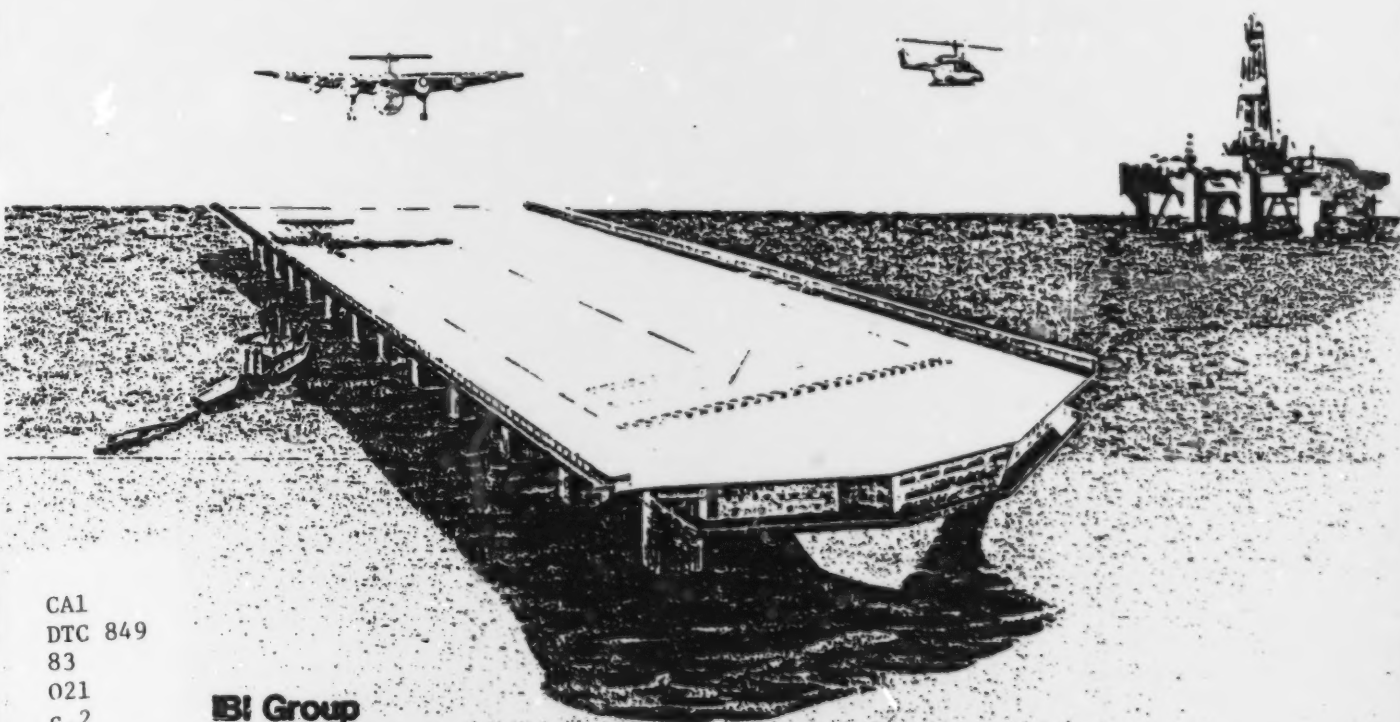


TP 5047

Transportation Development Centre
Canada

OFFSHORE AIRPORT CONCEPTS
SERVICING THE EAST COAST
ENERGY RESOURCE INDUSTRY
MAIN REPORT



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IBI Group
in association with
Albery, Pullerits, Dickson & Associates Limited
Seagem Incorporated

December 1983

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OFFSHORE AIRPORT CONCEPTS
SERVICING THE EAST COAST ENERGY RESOURCE INDUSTRY

SUMMARY REPORT

by

IBI GROUP

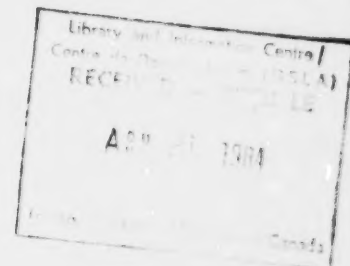
In Association With

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Seagem Incorporated

Authors

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December, 1983



The contents of this report reflect the opinions of the Consultant and are not to be construed as the official policy of the Transportation Development Centre.

Dimensions and measurements contained in this report may appear in both imperial and metric quantities as a reflection of common usage and standard practice of the aviation and marine industries.

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17. Abstract Energy resource developments in eastern Canada require the transport of personnel to and from installations location up to 200 n.m. offshore in one of the most severe of marine environments. The logistic requirements, the environment, safety considerations, regulatory and infrastructure needs and the application of STOL aircraft for offshore energy development have been investigated for three sites: the Scotian Shelf, Hibernia and the Labrador Sea. Environmental conditions of wave, weather and ice hazards along with likely traffic requirements are specified. Capital and operating costs are developed for offshore air terminals, both fixed and floating used as forward staging bases for either helicopter or STOL (Dash-7) operations. Total system costs are compared with a base case scenario of direct helicopter operations from the mainland. No offshore terminal concepts were found to provide sufficient transportation costs savings at current forecast traffic levels to offset initial capital costs. Fixed, bottom-founded heliports cost up to \$590 million; floating STOLports from \$250 to \$472 million and floating heliports from \$42 to \$110 million. However, incorporating crude oil storage facilities within the floating STOLport could substantially reduce the minimum traffic level required to justify the investment.					
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17. Résumé La mise en valeur des ressources énergétiques au large des côtes Est du Canada nécessite le transport d'effectifs à des distances pouvant atteindre 200 milles marins, dans des conditions climatiques extrêmement rigoureuses. Trois secteurs ont été étudiés: la mer du Labrador, Hibernia et le plateau continental près de la Nouvelle-Ecosse, et les exigences correspondantes déterminées du point de vue logistique, environnement, sécurité, réglementation et infrastructure, ainsi que l'utilisation d'ADAC. Le rapport détermine les états de mer et les conditions climatiques et glaciales auxquels il faut faire face. Il présente un devis des dépenses d'investissement et des coûts d'exploitation concernant les plates-formes d'atterrissage tant fixes que flottantes, utilisées comme base avancée soit par des hélicoptères, soit par des ADAC du type DASH-7. Le coût global du concept étudié est comparé à celui du concept de base faisant appel à des hélicoptères basés à terre. Aucun des concepts de plate-forme marine étudiée ne semble pouvoir apporter des économies suffisantes pour amortir les dépenses d'investissement initiales, du moins aux niveaux de trafic couramment prévus. Le coût d'héliports ancrés peut aller jusqu'à 590 millions de dollars, celui d'adacports flottants varie entre 250 et 472 millions et celui d'héliports flottants entre 42 et 110 millions. Néanmoins, l'idée de prévoir des réservoirs de pétrole brut dans l'enceinte d'un adacport flottant pourrait réduire appréciablement le niveau de trafic minimal justifiant les investissements à consentir.		
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A multi-disciplinary steering committee under the direction of the Transportation Development Centre was established to promote active participation and information exchange within government organizations, aviation and marine communities, and the petroleum industry.

PREFACE

This document describes research undertaken to identify and investigate feasible air transportation options for the support of offshore energy resource development in Eastern Canada.

Primarily concerned with the handling of passenger traffic, the objectives of this project were to identify and evaluate:

- o the opportunities for improved air transportation technology involving rotary winged aircraft and heliport facilities; Short Take Off and Landing (STOL) operations; artificial islands; SWATH personnel carriers; semi submersible hulls; tuned barges; associated navigational aids, and traffic control mechanisms, in support of offshore drilling operations.
- o the technical and economic feasibility of a floating airport and related technology for Canada.
- o the opportunities in Canada for high technology export or for internal self sufficiency and growth.

The following activities were carried out in order to achieve the objectives proposed.

- o Reviews and assessment of:
 - existing offshore resource development scenarios in Eastern Canada, and the modes of transportation currently employed
 - offshore energy resource development practices in the North Sea, for comparison purposes
 - demand forecasts for future offshore development
 - logistical requirements
 - state of the art technology for aviation, relating to rotary winged and fixed wing aircraft, Short Take-Off and Landing (STOL) aircraft and associated navigational aids
 - state of the art technology for marine architecture such as semi-submersible vessels and artificial islands
 - offshore aviation facilities standards
 - climatic information
 - certification and regulatory considerations.
- o Development of a series of Working Papers and analytical models to describe, analyze and evaluate the existing situation and the opportunities for improvement.
- o Preparation of summary report to document the results of the project work and provide a basis for possible implementation of the opportunities.

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1. INTRODUCTION

Transfer of personnel by helicopter between supply bases on Canada's east coast and offshore drilling platforms involves high operating costs, passenger inconvenience and unpredictable service due to adverse weather conditions.

Operating costs which are already high are expected to increase as traffic grows and as exploration and production moves to more remote locations.

Improved air navigation and landing aids and more comprehensive meteorological services will result in some improvements in service, but reductions in landing minima are likely to continue to be limited by the airspace constraints at the platform based helipads.

Passenger convenience will improve as larger, safer, and more comfortable helicopters are introduced into service. Speeds are likely to remain relatively low and the incidence of weather related delays will remain high. The effect of these two latter factors will become more pronounced as flying distances increase.

In this research study a number of systems were defined in conceptual terms for examining the practicability of improving the current system in the following areas:

- a) Reducing the costs and delays associated with rotary wing aircraft by:
 - o Introducing highly stable, fully instrumented offshore heliports, capable of serving as IFR alternates, thereby improving helicopter productivity;
 - o Introducing improved landing systems at special purpose heliports to reduce weather related delays;
 - o Grouping of flights to a centralized offshore heliport for distribution, thereby improving load factors on long hauls.
- b) Reducing aviation systems costs by substituting fixed wing STOL aircraft for rotary wing aircraft resulting in the following benefits:
 - o reduced aircraft operating costs;
 - o reduced flying time;
 - o Improved service quality, reliability and convenience;

-
- o wider choice in the number and location of onshore supply bases;
 - o increased scope for improved service reliability;
 - o economic benefits to the Canadian aircraft industry.
- c) Increasing the efficiency and reliability of fixed wing and rotary wing aircraft through improved navigation, communications systems and landing aids.
- d) Introducing at offshore heliports and STOLports advanced marine personnel transport vessels to reduce flying weather related delays.

The study showed that many of the current problems could be bettered by improved helicopter technology and support services, however, the greatest potential for improvement lies with introduction of fixed wing STOL aircraft operating from land to offshore floating airports. A number of such concepts were examined, and while all appeared to be technically feasible, their high capital costs offset the potential savings resulting from reduced aircraft operating costs. With some of the concepts, the deficits were marginal and as a result there is a strong possibility that one or more of them may prove economic if the actual traffic volumes surpass forecast levels. This appears to be particularly true for those STOLport concepts which combined airport facilities with crude oil storage.

Tilt wing/rotor concepts were also examined. Such aircraft have the advantage of the higher en route speeds associated with fixed wing aircraft and the vertical takeoff and landing capability of helicopters. Aircraft of this type are currently being tested by the U.S. military, but considerable work will be required to establish their viability in civilian applications.

The effectiveness of semi-submersible catamaran type passenger vessels was also studied but in less detail since they are marine vessels and do not lie completely within the scope of this study. These vessels, which are now entering service, have good operating characteristics in heavy seas, and can serve either as a primary or secondary transport mode depending upon the travel distances involved.

2. THE STUDY AREA

The three east coast geographic areas studied were: the Scotian Shelf (Sable Island area), the Newfoundland Shelf (Hibernia area), and the Labrador Sea area. Each area represents a distinct offshore/onshore system in terms of common elements such as:

- o climate and sea state;
- o a related group of offshore destinations;
- o a land-based airport, acting as a common supply centre;
- o alternate landside airports;
- o legal jurisdiction.

A circular zone 50 nautical miles in diameter was defined as the representative focus production activity for each of the three selected geographical areas (Figure 1). The three zones, and their supporting landside airports, allowed comparing the performance of the selected options over operating radii from 100 to 204 nautical miles. This range was increased to 250 nautical miles as part of a sensitivity analysis.

3. THE OPERATING ENVIRONMENT

The offshore climate is characteristically harsh and unpredictable. Although air temperatures are relatively mild in comparison with other regions of Canada, strong winds can result in severe wind chill and freezing spray. The seasonal sea ice, drifting icebergs and extreme sea state endanger moored vessels, while frequent periods of fog, low cloud and high winds hamper aircraft movements.

Offshore weather data was obtained from the computerized data bank of Environment Canada at their Atmospheric Environment Centre (AEC) in Toronto. This data was supplemented with published information from a number of Canadian and international sources. The AEC data had some limitations for aviation systems planning in that it was based on six hourly observations making it necessary to adjust it in order to obtain the hourly information necessary for estimating airport availability.



DISTANCE BY AIR Scotian Shelf

Halifax-Sable	180 nm
Sydney-Sable	133 nm
Yarmouth-Sable	223 nm

Newfoundland Shelf

St. John's-Hibernia	204 nm
Gander-Hibernia	290 nm

Labrador Sea

Goose Bay-	
Labrador Sea	187 nm
Hopedale-	
Labrador Sea	100 nm
Cartwright-	
Labrador Sea	138 nm

DISTANCE BY LAND

Halifax-Yarmouth	321 km
Halifax-Sydney	432 km
St. John's-Gander	331 km
St. John's-Argenteia	131 km
Goose Bay-	
Cartwright	210 km
Goose Bay-	
Hopedale	280 km

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EXPLORATION AREAS

figure 1

3.1 Marine Conditions

The safety and hydrodynamic performance of all marine concepts evaluated in this study were determined using computerized simulation models. The following wave specification was developed from available wind and sea state statistics:

- o extreme significant wave height of 18 metres;
- o maximum wave height of 36 metres;
- o maximum wave length of 600 metres;
- o maximum wave duration of 20 seconds.

Some 1,200 icebergs annually drift from the west coast of Greenland along the "iceberg corridor" into the vicinity of the Labrador Sea and the Newfoundland Shelf. The Scotian Shelf is essentially iceberg-free. Icebergs range in magnitude from "berg bits" and "growlers" under 1.5 metres in height, 5 metres in length and 1,000 tonnes mass to "very large bergs" over 100 metres high, over 220 metres long and one million tonnes mass. The review of sea ice and iceberg conditions indicated that floating facility operations would be seasonal at the Labrador Sea and subject to occasional disconnection at the Newfoundland Shelf. Bottom founded structures would require a grounding system for large icebergs, and would have to be capable of directly resisting the impact of smaller ones.

3.2 Aviation Weather

Major weather related factors which can limit flight operations are vertical ceiling and horizontal visibility, cross wind condition on landing, in-flight and platform icing and motion of the floating platform.

The most favourable flying conditions at the Scotian Shelf occur during the daylight hours of the fall and winter months. Extensive periods of fog and low cloud prevail at other times. Substantially worse conditions are experienced on the Newfoundland Shelf particularly during the months of March to August and the month of November. Labrador Sea area experiences generally good visibility conditions except during the months of July, December and January.

At present, helicopter operations are halted when the weather conditions fall below Instrument Flight Rules Category II. The Category II minima at the offshore platforms are 30 metres available ceiling and 400 metres available horizontal visibility.

One measure of airport availability is the probability of an airport being open on a given day for a specified period of time. Weather breaks during which operations are permissible are generally referred to as weather windows. Table 1 shows the estimated percentage of time that weather conditions at each of the three locations will be below Category II limits for weather windows from 1-8 hours in duration.

WEATHER WINDOW* (Hours)	SCOTIAN SYSTEM	HIBERNIA SYSTEM	LABRADOR SEA SYSTEM	
			ANNUAL	JUNE/NOV.
1	4(10)**	12(15+)	4(10)	2(2)
2	5(10)	12(15+)	4(10)	2(2)
3	5(10)	13+(15+)	5(10)	2(3)
6	7(10)	13+(15+)	7(15)	4(10)
8	10(10)	13+(15+)	7(15)	5(10)

Table 1 Estimated Percentage of Annual Weather Falling Below IFR Category II Minima Daylight Period

* Continuous period during which weather remains above Category II minima.

** Worst monthly percentage in brackets.

High winds hinder aircraft landings, especially when wind-shear, cross winds, freezing spray or poor visibility conditions are present. A floating airport operating in areas experiencing high winds must be capable of turning into the wind to minimize the lateral forces on landing aircraft. All three sites experience heavy winds over considerable periods of the year as shown in Table 2.

AREA	DIRECTION	WINDSPEED (KNOTS)	% OF TOTAL TIME
Scotian Shelf/ Sable	-	Calm (0-2)	3
	West	15 or more	38
	All	15 or more	47
	All	20 or more	28
	All	30 or more	16
Newfoundland Shelf/Hibernia	-	Calm (0-2)	2
	West	15 or more	32
	All	15 or more	43
	All	20 or more	32
	All	30 or more	3
Labrador Sea	-	Calm (0-2)	3
	West	15 or more	24
	All	15 or more	47
	All	20 or more	26
	All	30 or more	28

Table 2 Wind Characteristics

In-flight icing is a serious problem in the area because of the frequent occurrence of high humidity and freezing temperatures. Helicopters are particularly susceptible. De-icing systems are becoming increasingly available and research is continuing to improve their cost effectiveness. The Dash-7 has de-icing equipment on its critical aerodynamic surfaces and because it is pressurized, it can in some instances fly above the icing atmospheric layer.

Freezing spray occurs at all three offshore locations from late autumn to mid-spring depending upon sea state, wind, temperature and precipitation. Average mean temperatures of less than 5°C can occur from December to April at the Scotian and Newfoundland Shelf areas and from October to May at the Labrador Sea area. Freezing salt spray is also a problem since it can result in sudden aircraft icing, airframe corrosion, reduced visibility and skidding upon landing.

Accurate and comprehensive offshore weather information is therefore viewed as a special requirement, unique to each location, and can best be improved by locating sensing equipment and transmitter installations in proximity to the offshore area of interest. This is especially critical for gathering information on the correlation between visibility, winds and sea states, factors which are becoming increasingly significant because of the prevalence of IFR Category II and Category III weather. Better

data will be required to assure the viability for future automatic landings (Category IIIa) for both fixed wing and rotary wing aircraft. It is recommended that consideration be given to the development of data programs which would show correlation between ceiling/horizontal visibility, winds and sea state, upon which estimates of availability of offshore landing facilities can be based.

4. NAVIGATIONAL AIDS AND COMMUNICATION SYSTEMS

At present, because of the small number of aircraft in service in the offshore areas, only limited en route navigation, communication and air traffic control services/flight services (ATC/FSS) systems are available. Interim procedures have been established by agreement between the air carriers and controllers. Shore based Very High Frequency Omni-directional Radio-range/Distance Measuring Equipment (VOR/DME) is used for positive positioning within range of shore-based coverage. Non-directional beacons (NDB) and air-borne radar transponders are used in the vicinity of the rigs; positive radio communication is available and flight plans are filed with and approved by Transport Canada.

There will be a requirement to standardize on a single long range en route navigaid system, possibly LORAN C or OMEGA, supplemented by VOR/DME installations. Consideration should also be given to the installation of offshore peripheral (PAL) communications facilities to ATC centres to improve air traffic control in the vicinity of the platforms.

A representative system might include Very High Frequency AM radio at the PA site for communications with aircraft in the area and a high power High Frequency Single Side Band radio link to the mainland ATC.

Consideration should be given to the provision of more precise weather briefings, and more formalized ATC/FSS services. In future, as operations are expanded, additional control of the offshore airspace will be desirable, possibly requiring its locating of ATC/FSS units, complete with personnel and equipment at the offshore STOLports and heliports.

5. TRAFFIC DEMAND

The traffic demand estimates for the study were based on the number of platforms likely to be active simultaneously within each of the delineated zones during the production stage.

Alternative development strategies are under consideration by the oil industry are:

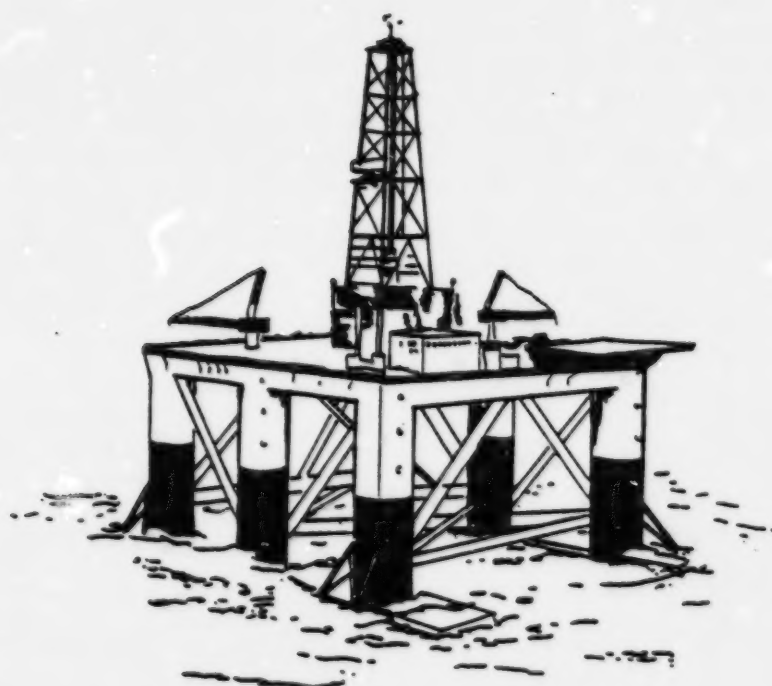
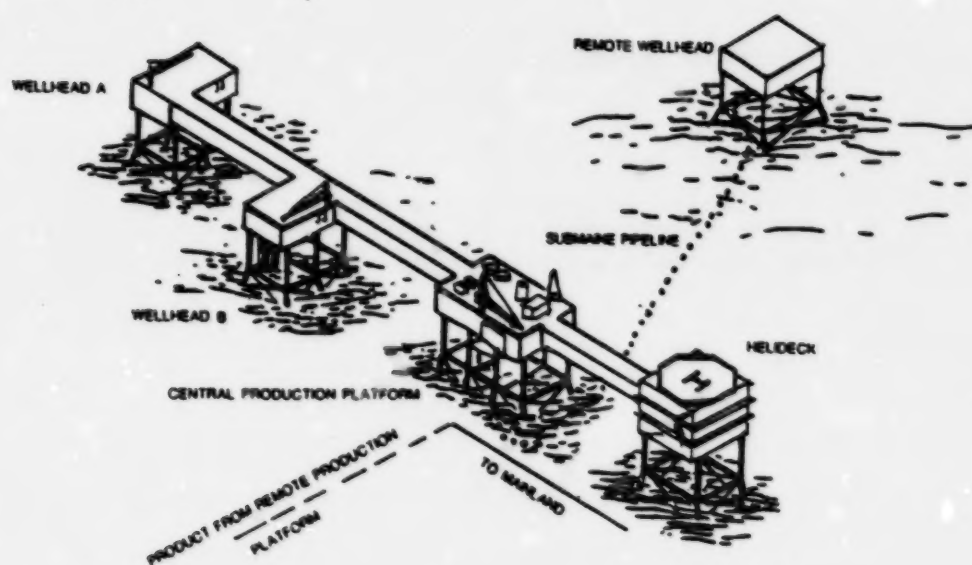
1. A centralized strategy involving large production platforms capable of directly tapping an area of approximately 6.4 square kilometres and connected by undersea pipeline, to three or four satellite wells by undersea pipeline.
2. A decentralized strategy involving groups of up to four smaller platforms each capable of tapping an area of approximately one square kilometre.

The intention is to employ the decentralized strategy on the Scotian Shelf. The strategy for the Hibernia system is undecided and is even less certain for the Labrador Sea area. The centralized strategy would require slightly fewer personnel but the differences between the strategies are not insignificant and so for the sake of simplicity, the traffic levels corresponding to the decentralized strategy were adopted.

Table 3 shows three forecasts of employment prepared on the basis of present expectations. Annual person trip forecasts were developed by assuming one, two and three week average rotation periods for based employees.

CASE	BASED EMPLOY- MENT	ANNUAL PERSON TRIPS ROTATION RECORD		
		1 WEEK	2 WEEK	3 WEEK
Minimum	400	41,600	20,800	13,900
Most Likely	850	88,400	44,200	29,500
Maximum	1,600	166,400	83,200	55,400

Table 3 Forecast Employment and Trip Levels



TYPICAL OFFSHORE PRODUCTION COMPLEXES

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figure 2

Several of the concepts were not viable within the forecast range of traffic and therefore the upper traffic level was arbitrarily increased to 300,000 annual person trips, a level which exceeds the breakeven point of all but one concept.

6. SYSTEM ALTERNATIVES

Three distinct systems concepts were developed for evaluation and for comparison with current or base case operations. These options, and the base case scenario (Direct service from shore base to drilling platform) are illustrated on Figure 3.

The systems studied included:

- o existing direct helicopter service;
- o fixed offshore heliports;
- o floating heliports;
- o floating STOLports.

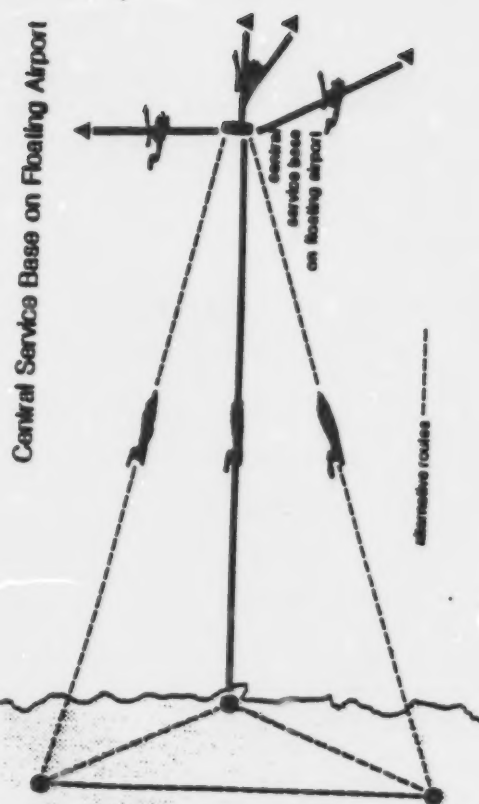
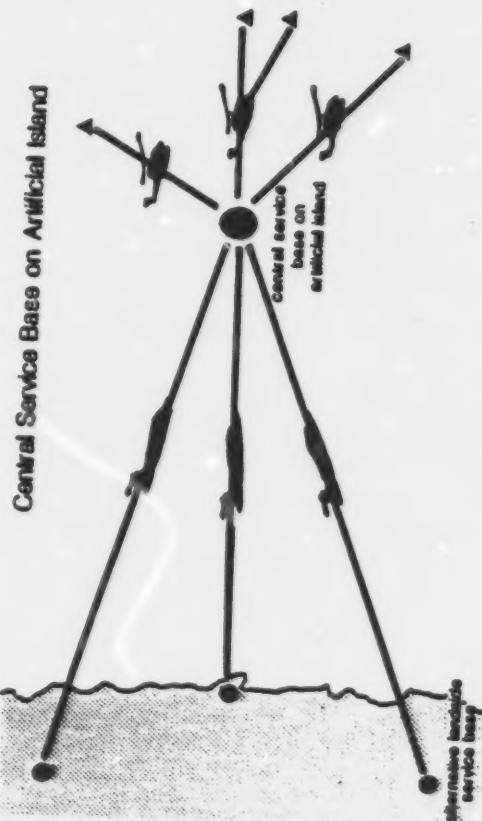
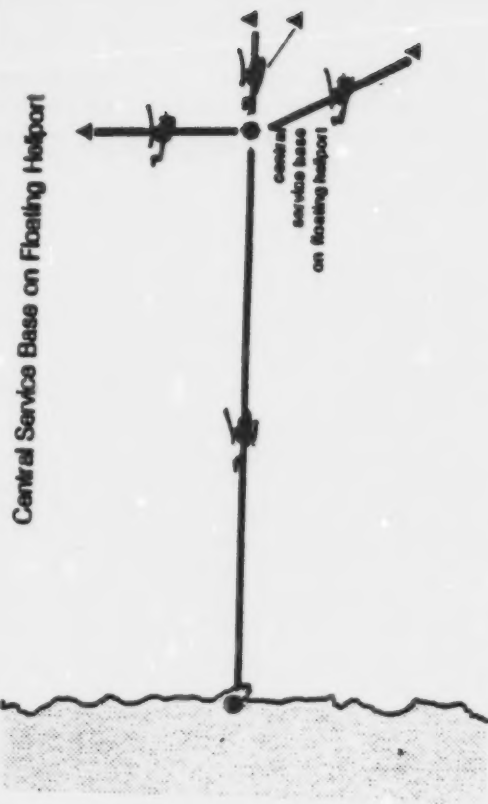
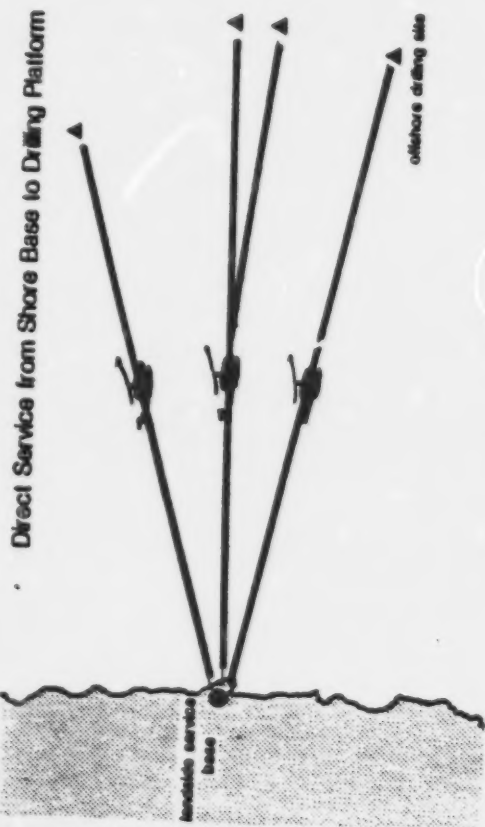
6.1 Existing Direct Service (Base Case)

In order to assess the technical and economic feasibility of improving the existing service, each major system component was examined in the context of the following variables;

- o geographical location of the offshore production areas;
- o number and location of onshore supply bases;
- o aerial distances between onshore bases and offshore location;
- o number of platforms to be served by a single flight;
- o based employees per platform;
- o staff rotation period;
- o flight frequencies;
- o aircraft capacity, range and operating cost.

This evaluation took into account forecasts of demand and the likely timing of technological advancements. Technological improvements outside of the time frame of the study were not examined.

Analyses indicated that production operations would likely fall within the following range:



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OPTIONS FOR OFFSHORE RESUPPLY

figure 3

Range of platform size	- 100-200 based employees
Staff Rotation Period	- 2 or 3 weeks
Minimum Flight Frequency	- 182 days annually
Platforms in one flight circuit	- 2
Load Factor	- 85% Average

Unit transportation costs were calculated for each combination of variables resulting in the values shown in Table 4 below.

SYSTEM	ONSHORE BASE(S)	MAX. UNIT COST	MIN. UNIT COST	AVERAGE UNIT COST
Hibernia	St. John's	439	367	403
Labrador Sea	Hopedale	229	163	196
	Cartwright	313	232	272
Scotian Shelf	Halifax	331	275	253
	Halifax/Sydney	377	282	329
	Halifax/Sydney/Yarmouth	451	363	407

Table 4 Summary of Base Case Costs - One Way Person Trip Costs (Dollars)

6.2 Artificial Island or Bottom Founded Structure Heliports

This alternative envisages a shuttle service utilizing a large passenger helicopter to provide services to artificial island based heliports or offshore bottom founded structure heliports.

Transport of passengers from the offshore heliport to individual rigs would be conducted by smaller helicopters by loop service or by special marine vessels.

The selected facility would be designed and equipped to qualify as an IFR alternate. It would be equipped as a forward supply and support base with high performance nav aids, landing aids and communications facilities.

A bottom founded gravity base platform is an alternative solution to the artificial island for deep water locations. At the Virgin Rocks site, where the water is relatively shallow, both

the artificial island and bottom-founded gravity structure concepts are feasible.

6.3 Floating Heliports

A shuttle service by large, shore based helicopters could serve a floating offshore heliport where they would interface with smaller helicopters providing a loop service to a collection of rigs or to individual rigs. The landing limits on the platform would be lower than those likely attainable on the individual platforms.

Employees could be transferred directly from the primary helicopter to the local service or could be held on the facility during periods of adverse weather to take advantage of short weather breaks. Marine vessel backup for secondary distribution could be provided to reduce delays in the secondary systems.

A sub-alternative of this option would be to use the floating facility as an IFR alternate to improve efficiency of direct helicopter services.

6.4 Floating STOLports

The floating STOLport system concept envisages the accommodation, offshore, of a shuttle service by shore based fixed-wing aircraft having the short take-off and landing capability of the de Havilland Dash-7. At the STOLport the fixed-wing aircraft would interface with offshore based helicopters which would provide the link between the floating STOLport and the individual platform. An extension of the concept would be the provision of supplementary STOL services from other shore based airports in the vicinity.

The preliminary analysis showed that a semi-submersible STOLport might not be justifiable because of low forecast traffic volumes; a less costly floating STOLport barge concept was therefore introduced. This latter concept had the additional advantage of providing a crude oil storage capability at the production site, which if utilized, could help defray the operating costs. Two barge concepts were studied. These were the Seaforth Maritime tuned barge, designed to have superior motion characteristics under design sea states and a concept developed by Albery Pullerits Dickson & Associates in which the barge would be fabricated from five surplus very large crude carriers (VLCC's).

6.5 Semi-Submersible Catamaran Vessels

The study of the operating environment and related air navigation and landing aid requirements indicated that floating STOLports and heliports might be safely operated at lower ceiling

and visibility limits than could helipads on drill rigs and production platforms. To overcome this problem, a marine service utilizing vessels of the semi-submersible catamaran (SWATH) type could substitute for, or act as backup to the offshore based helicopters.

7. AIRCRAFT OPERATING CHARACTERISTICS & COSTS

7.1 Helicopters

Five helicopters were selected to cover the variation in payload/range implicit in the study forecasts for the three designated production areas. Their payload/range characteristics are summarized in Table 5 and indicative fixed and hourly costs Table 6. A composite cost curve was developed from this data for each site over the assumed passenger demand range. These estimated costs, are based on a number of assumptions and approximations but are sufficiently accurate for concept evaluation purposes.

7.2 Fixed Wing Aircraft

The Dash-7 was selected as the preferred fixed wing aircraft. It is widely operated throughout the world and has satisfactorily demonstrated its advantages in STOL operations. Its avionics system meets FAR 25 certification standards and area navigation (RNAV) and microwave landing systems (MLS) are available options. This aircraft is uniquely suited for this application by virtue of its reliability, short runway requirements, payload/range performance and low operating costs.

Operating characteristics of the Dash-7 are itemized in Table 7 and fixed and hourly operating costs are shown in Table 8.

CHARACTERISTICS	TYPE OF HELICOPTER				
	S-76	S-61N	214ST	AS332L	BV234LR
Preferred Cruise Speed (knots)	135	110	130	135	135
Max. IFR radius of action at economical speed (nm)	265	225	250	300	335
Actual seating capacity used for east coast operations	8	17	16	16	-
Passenger/payload range with IFR reserve (nm)	people*	people*	people*	people*	people*
100	11	23	16	22	44
150	8	19	16	22	44
200	6	15	13	22	44
250	4	-	10	16	44
300	-	-	-	13	25
Distance/flying time range**	minutes	minutes	minutes	minutes	minutes
50 nm	22	27	23	22	22
100	45	55	46	45	45
150	67	82	69	67	67
200	89	110	92	89	89
225	100	124	104	100	100
250	111	-	115	111	111
275	-	-	-	123	123
300	-	-	-	133	133

Table 5 Rotary Winged Aircraft Characteristics

* 100 kg average for passengers luggage and immersion suit.
 ** Does not include manoeuvring time.

	S-76	S-61N	214ST	AS332L	BV234LR
<u>1. Capital Cost</u>					
o 1982 aircraft cost	2,750,000	3,000,000	4,880,000	5,000,000	16,640,000
o Spares	340,000	380,000	610,000	630,000	2,080,000
o Total capital	3,090,000	3,380,000	5,490,000	5,630,000	18,720,000
<u>2. Fixed Charges</u>					
<u>a) Personnel</u>					
o Pilots	160,000	160,000	160,000	160,000	160,000
o Technicians	144,000	144,000	144,000	144,000	144,000
o Extra crew	-	-	-	-	72,000
o Dispatch/Office	40,000	40,000	40,000	40,000	40,000
Sub-total	344,000	344,000	344,000	344,000	416,000
<u>b) Depreciation</u>	233,750	255,000	414,800	425,000	1,414,400
<u>c) Insurance</u>	165,000	180,000	292,800	300,000	998,400
<u>d) Interest Charges</u>	173,800	190,125	308,800	316,700	1,053,000
<u>e) Management Charges</u>	300,000	300,000	300,000	300,000	300,000
<u>f) Profit</u>	297,000	303,500	402,900	432,000	1,040,000
o Total fixed annual	1,513,550	1,572,625	2,063,300	2,117,700	5,222,200
o Fixed per month	126,000	132,000	172,000	177,000	435,000
<u>3. Hourly Charge</u>	440	510	590	790	1,700
<u>4. Annual Cost*</u>	\$2,132,080	\$2,408,530	\$2,916,540	\$3,239,540	\$7,723,740
<u>5. Average Cost per hour for 1,000 hours*</u>	\$2,132.08	\$2,408.53	\$2,916.54	\$3,239.54	\$7,723.74

Table 6 Summary of Indicative Helicopter Costs

* Includes: fixed monthly charge, hangarage, hourly charge (primarily maintenance), fuel and oil and landing fees. Cost of immersion suits for passengers, is not included. (Basis 1,000 hrs.)

DESCRIPTION	VALUE	COMMENT
Seating Capacity	50 people	At 81 cm Pitch, Maximum 54 Seats
Maximum Cruise Altitude	7600 m	
Take Off Weight (Max.)	20,000 kg	
Landing Weight (Max.)	19,091 kg	
Fuel Capacity	2,545 kg	
Maximum Cruise Speed	231 Knots	At 2432 m ASL, 227 Knots 4560 m ASL
Range	500 nm	50 passengers at 100 kg, IFR reserves 100 nm, Diversion, + 45 mins. fuel LRC
Maximum Range	1,100 nm	As above except payload 35 passengers at 100 kg each
Take Off Field Length	687 m	FAR 25, 25° flaps, zero wind, ISA - Sea Level, Payload 20,000 kg
Landing Field Length	593 m	STOL, 45° flaps, screen length 10.6m, speed 1.3V _{SO} , dry based landing surface zero wind, field length factor 1/0.6, weight 19,091 kg.
Crosswind Capability	15 knots	Under IFR Cat 11 conditions (in excess of 20 knots, VFR conditions)

Table 7 Dash-7 Capability

1. <u>Capital Cost (\$ Canadian)</u>	
o 1983 Aircraft Cost	\$ 8,500,000
o Spares (10%)	850,000
o Total Capital Cost	<u>9,350,000</u>
2. <u>Fixed Charges</u>	
o Depreciation	673,200
o Insurance*	280,500
o Interest*	701,300
o Management and Base Costs*	300,000
o Crew*	393,000
o Profit	650,000
o Total Fixed Charges	<u>2,998,000</u>
3. <u>Hourly Charges</u>	
o Maintenance (\$254)*	635,000
o Fuel and Oil (\$377)*	942,500
o Total Hourly Charges	<u>1,577,500</u>
4. <u>Total Annual</u>	4,565,500
5. <u>Total Hourly</u> (2,500 black hours)	1,825

Table 8 Summary of Estimated Dash-7 Costs

* Included is cost figure for profit estimate.

8. ALTERNATIVE OFFSHORE HELIPORT CONCEPTS

8.1 Alternative Solutions

The heliport transportation system options considered in this study involved two types of offshore base, either a floating structure or an artificial island. Both could accommodate rotary wing operations, as well as providing hangarage, materials, storage, accommodation for personnel, and navigational aids. The concepts considered included:

-
- o artificial islands
 - o bottom founded gravity based structures
 - o tension leg platforms
 - o semi-submersible platforms
 - o VLCC conversions.

8.2 Iceberg Considerations

A major consideration in the design of artificial island heliports and bottom founded structures is the threat of iceberg collision.

A berm can be used as the first line of defence against large icebergs. Selection of its dimensions is based upon a trade off between the magnitude of impact the structure is designed to withstand and the size and weight of armour that can be practicably manufactured and placed.

A second line of defence against icebergs for bottom founded structures can be a system of arresting cables or fence. The concepts studied assumed vertical arrestors located on the periphery of the structure made up of several large wire rope cables enclosed in sheaths and connected to opposite sides of the base of the structure and looped through the deck.

To cover the event of cable failure or non-performance, it was assumed that the stem and base of the structure would be designed to withstand the full impact of a 1 million tonne iceberg. A horizontal force of 25,000 tonnes was assumed to act on the system and the structures were designed with an adequate safety factor to counteract overturning and sliding forces.

8.3 Artificial Islands

Simple artificial islands have been extensively used in the Beaufort Sea as exploration sites. These berms, constructed of local granular material dredged from the seabed are usually located in shallow waters of 13 to 15m in depth. In deeper waters, caisson retained sand islands are generally used in order to minimize fill quantities.

A number of artificial island designs envisaging concrete cores and iceberg arrestors are currently under consideration. The concepts are becoming more sophisticated with consideration being given to the provision STOL runways, artificial harbours, and offshore petroleum storage and production facilities. Extension of the artificial island concept are reinforced concrete bottom founded or "gravity base" platforms which have been built to accommodate oil production facilities in the North Sea. These structures are massive, constructed onshore and towed to permanent sites. They have been placed in water depths of up to 150m, and

are capable of withstanding hostile seastates not unlike those found off Canada's east coast.

8.4 Gravity Base Heliport, Virgin Rocks

The Virgin Rocks are comprised of Prairie Shoal, Main Ledge and South Shoal. They are 15 km long and are located 200 km southeast of St. John's, and 150 km southwest of the Hibernia development area. One concept studied for this site involves locating a helideck supported by a pedestal gravity base the structure founded on the Main Ledge in waters between 10 - 15m in depth. The shoals would serve to ground large icebergs and structure itself would be capable of resisting the overturning and sliding forces of smaller icebergs. The deck would be of steel construction with a diameter of 120m and would be constructed in a shipyard. Two designs were investigated for the supporting structure. One envisaged a 20m diameter compartmentalized base which would be towed to the site and sunk to rest on the prepared crushed stone mattress laid on the shoal. The core of the pedestal would then be filled with crushed stone and cement, grouted to prevent erosion and collapse.

The second alternative envisaged a semi-submersible design in which the deck superstructure would be supported by eight circular legs mounted on an octagonal base resting on a crushed stone mattress placed on the shoal. This structure would be anchored in place, ballasted and cement grouted to ensure its adherence to the mattress and to protect the anchor casings.

8.5 Bottom Founded Heliport Structures - Deep Water

The proposed structure for deep water applications would have a diameter of 120m, attached to a pedestal and base embedded in a sand berm 80m below sea level. The concept is shown on Figure 4.

The unit could be constructed by fabricating the bottom slab and a portion of the walls of the cellular base at a drydock. The partially finished base could be floated to brestle and the base and stem completed. The deck, fabricated elsewhere, would be floated to the site in halves, each mounted on a catamaran-type vessel formed by parallel barge hulls adequately spaced and with sufficient freeboard to permit the tank deck section to pass over the top of the floating concrete base. The catamaran would then be lowered to set the tank sections onto the base allowing permanent connections to be completed.

Initially, the cellular base would have sufficient buoyancy to support itself and the deck. After sinking it would be fully flooded to increase its resistance to sliding and overturning. The deck tank would be raised on hydraulic jacks to its final

position and connected to the concrete stem. Iceberg arresting cables would be fastened and the berm completed to its final elevation.

The structure can be entirely built in Canada using conventional techniques and facilities.

8.6 VLCC Helipad

This concept involves the conversion of a surplus very large crude carrier (VLCC) or supertanker, into a floating helipad.

The selected tanker would be transferred to a drydock where surplus equipment and structural components would be removed and the deck converted into a helipad. Maintenance, air traffic control facilities, nav aids and landing aids would be constructed or installed as would a turret mooring system.

Compared with a fixed helideck, the VLCC helipad will have reduced availability for aircraft landings during adverse sea states. To minimize motion, the touchdown point could be located at the centre of gravity of the vessel. During extreme seastates or under threat of iceberg collision, the vessel would be disconnected and relocated.

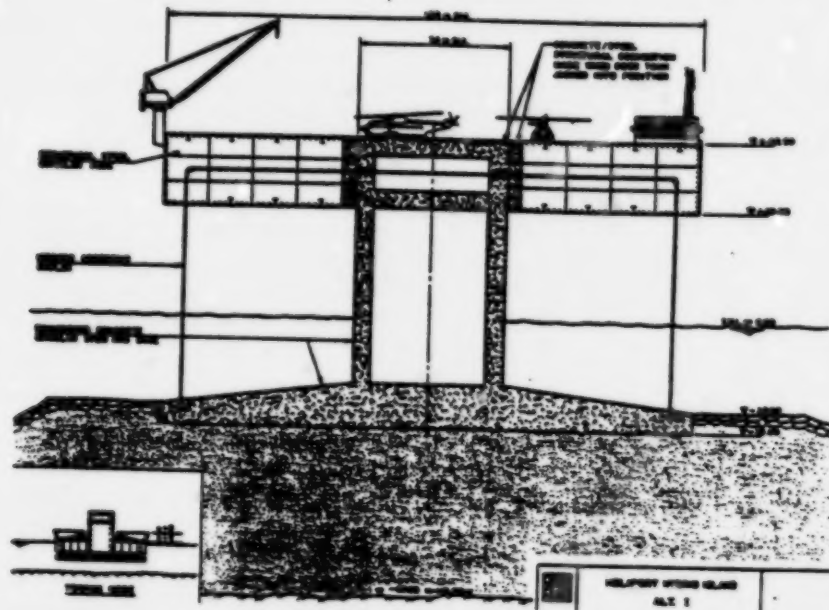
8.7 Tension Leg Helipad

The concept of a tension leg platform (TLP) for use as a helipad was included to provide a cost comparison with other alternatives.

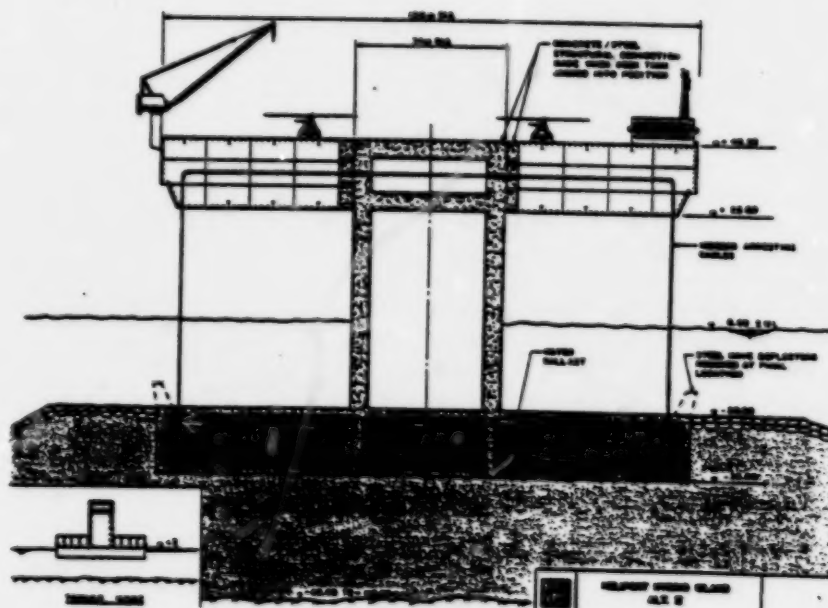
The TLP would be designed to operate in water depths of 80 to 110 metres. The vessel would be similar to the semi-submersible platform and would be fabricated from structural steel. It would rest on a bottom founded octagonal pontoon supporting the eight legs, which in turn supports the 120 metre diameter heli-deck. This concept is shown on Figure 5.

The mooring system would consist of a series of wire rope anchor cables connecting each leg to the gravity anchor. In non-rock locations the anchor could be piles driven into the seabed. The wire rope cables would be contained in sheaths which would be filled with a corrosion inhibitor. The gravity anchor would be fabricated as an open structural steel caisson, which, prior to vessel towing, would be attached to the anchor cables and winched to the underside of the pontoon.

At the anchorage site, the caisson would be lowered to the sea bed and filled with concrete. The vessel would then be sunk to allow the anchor cables to be tightened and then debal-
lasted to achieve the desired tension in the mooring cables. The



Alternative 1



Alternative 2

ARTIFICIAL ISLAND CONCEPTS: HELIPORT HYBRID ISLAND

figure 4

vessel would have sufficient buoyancy to maintain adequate cable tension during the passage of the critical 36 metre wave to prevent jerking.

Heave, pitch and roll movements would be reduced to near zero, however, horizontal movements would be possible. Its low vertical response would increase the availability of the heliport for aircraft operations. As with other vessels, it would have to be disconnected and moved out of the area when threatened by ice or icebergs.

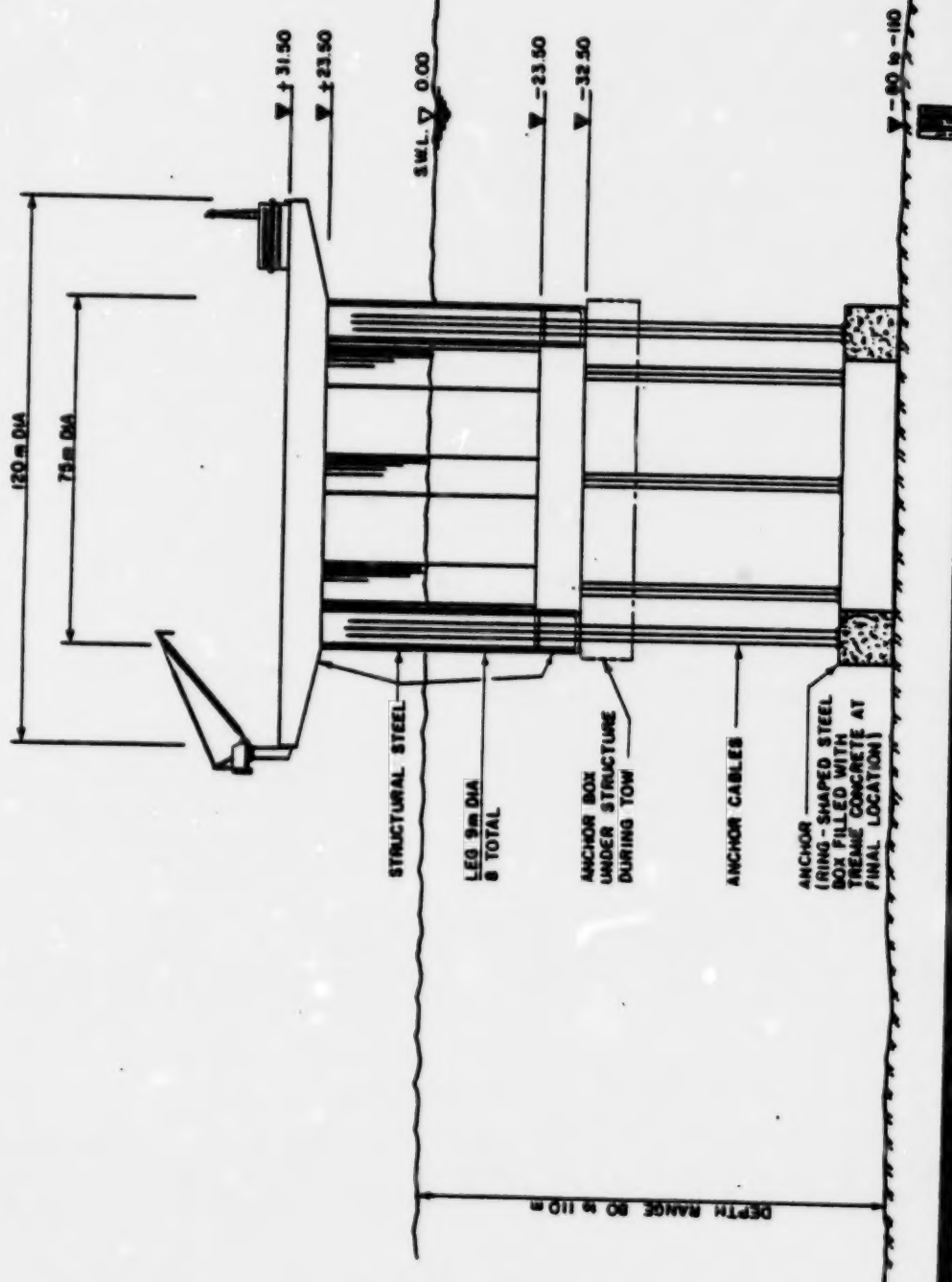
8.8 Semi-Submersible Heliport

A semi-submersible heliport platform could be designed using conventional platform technology. Design and construction features are well understood, and provision of the special purpose features associated with heliport operations would pose no significant problems. The structure could be designed to have good motion response, and would cost approximately 15 percent less than the equivalent tension leg platform.

8.9 Cost Comparisons

The capital cost of a berm or filled caisson artificial island heliport would be highly dependent upon local site conditions and material availability. In deep waters their costs would probably exceed that of bottom founded gravity structures, but in shallow locations, with good material availability, they would cost less. It was assumed that all artificial island concepts in deep water including those employing bottom founded gravity structures would have similar costs of \$590 million. The Virgin Rock bottom founded structure, located in shallow water was estimated to cost \$95 million.

The capital and annual operating costs, assuming a 12 percent rate of interest and a 15 year capital recovery period are shown in Table 9.



**FLOATING HELIPORT CONCEPT:
HELIPORT TENSION LEG STRUCTURE**

figure 5

ITEM	ARTIFICIAL ISLAND HELIPORT	VIRGIN ROCK HELIPORT	VLCC HELI- PORT	TENSION LEG HELIPORT	SEMI SUBMERSIBLE HELIPORT
A. Capital Cost	560	95	41	116	100
B. Annual Capital Recovery & Interest	81.8	13.9	6.0	16.9	14.6
C. Crew	3.8	3.8	6.6	4.4	4.4
D. Fuel	0.5	0.5	3.2	1.0	1.0
E. Maintenance	8.4	1.4	.6	1.7	1.5
F. Insurance	2.8	.5	.2	.6	.5
G. Aviation Electronics	1.2	1.2	1.2	1.2	1.2
TOTAL	98.5	21.3	17.8	25.8	23.2

Table 9 Annual Capital and Operating Costs
Offshore Heliports
(\$ Millions Canadian 1983)

8.10 Operating Alternatives

Two types of offshore heliport operating systems were compared against base case operations. These were:

Group A - Operating System - In which the heliports would be located near the centroid of employment and employees would be transported from the shore base by a common helicopter service connecting with an offshore helicopter shuttle operating to the individual production platforms (Hub and Spoke System).

Group B - Operating System - In which the heliport would be designed to meet future Transport Canada standards for an IFR alternate, and would be used as an intermediate landing facility by helicopters flying directly to the offshore production platforms.

8.11 Evaluation of Heliport Alternatives

The principle potential benefit of operating system A was a possible reduction in costs through more effective utilization of helicopters on a combined primary service serving a central hub.

A secondary benefit is increased service reliability attributable to the improved navigation and landing aids that could be provided and to the lower landing limits made possible by an unobstructed landing surface. Disbenefits would primarily result from the increased costs and passenger delays associated with the operation of the offshore helicopter services from the hub to the platforms.

For the Hibernia system the cost of transferring passengers by this system were estimated to be approximately \$1,275 per person trip--primarily because of a high capital cost component. The corresponding base case costs were estimated at between \$367 and \$439 per person trip. The system would be even less economic at the other two locations because of the shorter flying distances involved.

The costs estimates are highly sensitive to heliport capital cost. For example, if it were possible to convert a surplus semi-submersible platform at a capital cost of say \$10 million, the cost of a person trip would be reduced to between \$869 (25,000 annual trip level) to \$350 (300,000 annual trips). The breakeven point would lie between 125,000 to 270,000 total person trips annually for the Hibernia case. For the system to be economic, the delays arising from personnel transfer between the two trip stages would have to be substantially offset by reductions in weather related delays.

Operating System B assumes that an offshore heliport could be built and equipped to the standards necessary for licensing as an IFR alternate by Transport Canada. The standards pertaining to such facilities do not currently exist but, the underlying assumption in the analysis was that the required facility could be constructed for the capital costs outlined in Table 9.

The principle benefit of this operating system is that an IFR alternate heliport located en route would allow more effective utilization of some helicopters with short operating ranges and low operating costs. During the sensitivity analysis it was found that for a 300 nautical operating radius, a suitably located IFR alternate could reduce operating costs by approximately 35 per cent or by about \$140 per person trip.

The breakeven traffic level for the various heliport options were estimated to be:

HELIPORT ALTERNATIVE	APPROXIMATE BREAK-EVEN LEVEL ANNUAL PERSON TRIPS (1000's)
Artificial Island	703
Virgin Rocks	152
VLCC	127
Tension Leg Structure	184
Semi-submersible (new)	140
Semi-submersible (conversion)	72

Table 10 Break-even Traffic Levels Offshore
IFR Alternate Heliport

If conversion of surplus semi-submersible production platforms could be achieved for say \$10 million, the break-even trip level could be as low as 72,000 annual person trips.

9. FLOATING STOLPORT CONCEPTS

9.1 Concepts Considered

Three alternative floating STOLport concepts were considered including:

- o a semi-submersible STOLport as developed by Seaforth Maritime in collaboration with the de Havilland Aircraft of Canada Ltd.;
- o a specially designed barge STOLport or "tuned barge" developed by Seaforth Maritime, having oil storage capability;
- o a converted VLCC barge concept developed by Alberty Pullerits Dickson & Associates, having crude oil storage capability, as an option.

9.2 Semi-Submersible STOLport

The concept of a floating, all-weather runway for fixed wing aircraft operations on the high seas is well known in military applications, but a carrier with the dimensions required to support a 90m wide by 602m long runway has not been built to date. Apart from accommodating aircraft operations, the vessel

must also provide for related services such as aircraft hangars, vehicle parking, maintenance shops, fuelling, personnel accommodations, survival equipment, medical facilities, and storage. Equipment for transferring fuel and other supplies from support vessels must also be provided on board.

This floating vessel design shown on Figure 6 has a turret mooring system to allow the vessel to rotate 360 degrees. Under most conditions the runway will "weather vane" and head into the prevailing wind, the most desirable orientation for aircraft operations. In some instances, strong seas may cause the vessel to orient in a direction contrary to wind direction. This situation may be compensated for with the use of dynamic positioning equipment, to attain a balance between vessel response to waves and wind effect on landing aircraft.

When self-propelled, the vessel can relocate so as to shorten travel distances to the various offshore platforms. Also, under threat of ice and iceberg collision, the vessel can stay off anchor in readiness to move from the area. If a self-propulsion capability is not available and a support vessel must be provided.

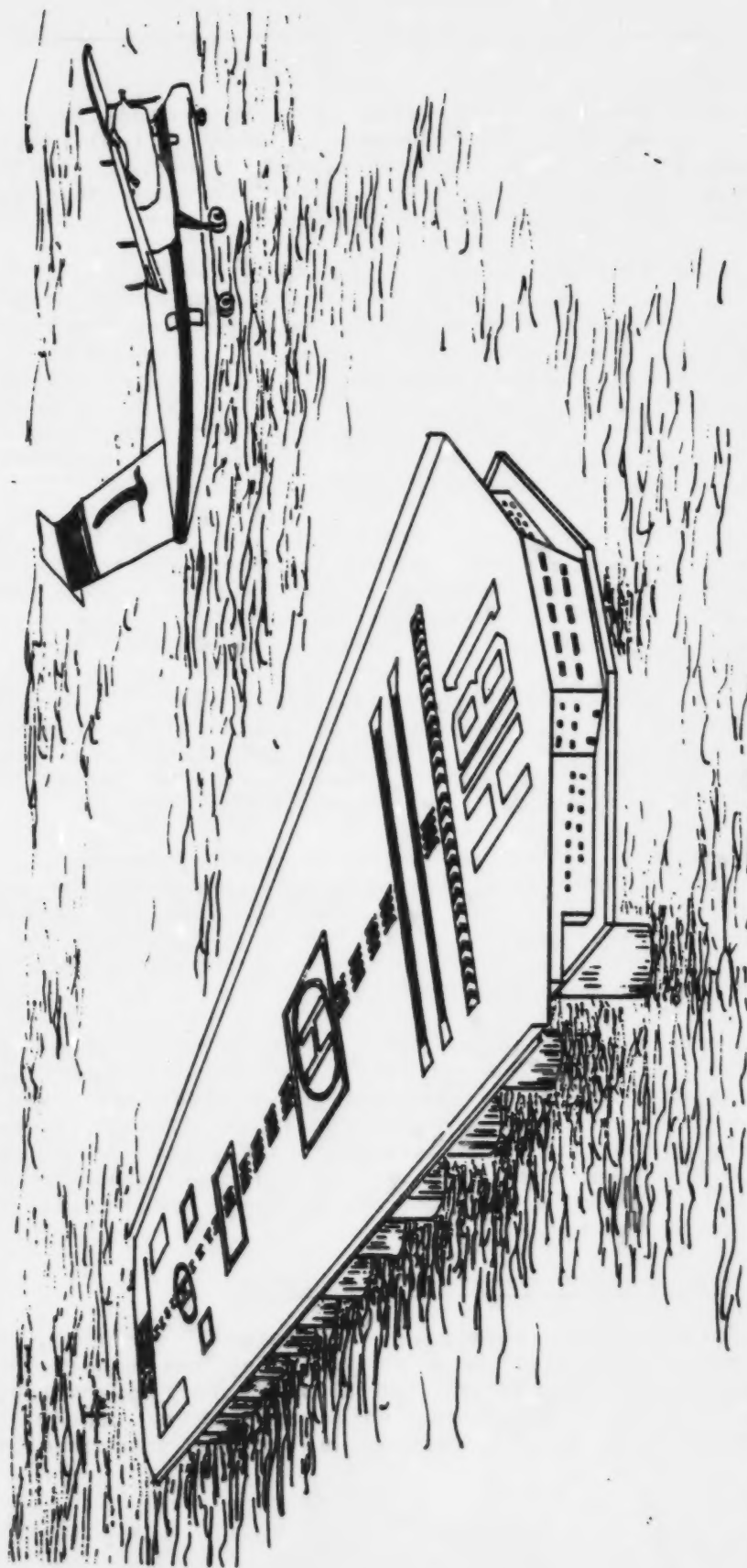
The vessel will respond to the action of waves in terms of transitory and angular displacements, velocities and accelerations. Its configuration determines the level of these responses which can limit the operation of aircraft during take-offs and landings.

The "design" extreme seastate in the three geographical areas considered in the study is to comprise waves of the order 18m and at extreme, 36m, with wave duration periods greater than 20 seconds. Wave lengths equal to the length off the vessel are therefore possible. Structure and anchor integrity must be maintained under these conditions.

Other extreme environmental events to be considered are sea ice and icebergs. Theoretically, the STOLport could be reinforced to withstand the forces imposed by sea ice, and small bergs, but the anchor would remain as the weak link. Therefore, when threatened by ice or icebergs, the vessel would have to be disconnected and moved. Under most circumstances, when relocated, it would remain within operating range of the exploration and production platforms.

9.3 Seaforth Maritime Tuned Barge

This concept developed by Seaforth Maritime, envisages a STOLport constructed as a barge having the special hydrodynamic characteristics necessary for STOL aircraft operation. Computer model studies by the firm indicated that by carefully selecting the dimensions of the vessel, its motion characteristics can be



Seaforth Maritime Limited / The de Havilland Aircraft of Canada

SEMI-SUBMERSIBLE STOLPORT

figure 6

adjusted to compare favourably with those of semi-submersible STOLports. The tuned barge concept is shown on Figure 7 and its characteristics in Table 11.

Barge Length	570 m
Width	76 m
Depth	41 m
Design Draught	18 m
Flight deck (upper level) length	602 m
width	90 m
- 16 crude oil storage tanks - total capacity	380,000m ³
- oil storage - midship	
- aircraft hangars - aft or midship	
- segregated ballast tanks	
- Inert gas system	
- 30 bed hospital with operating theatre	
- computer room	
- meteorological facilities	
- crew and other accommodation	up to 320
- survival equipment & emergency rescue launch	
- shielded arrestor nets	

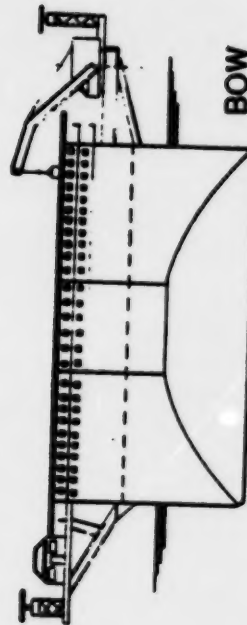
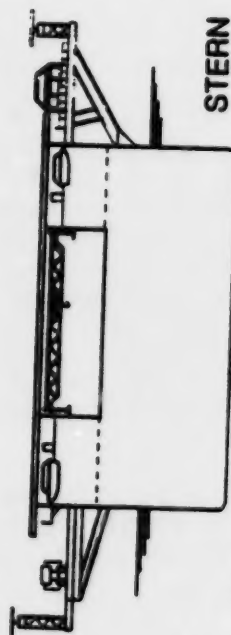
Table 11 Tuned Barge Design Characteristics

Separate floating oil storage and loading facilities have been under review for service off Canada's east coast including the possible mooring of a million barrel oil storage and loading vessel connected by pipe to up to four semi-submersible production platforms.

The tuned barge, incorporating crude oil storage facilities could at some locations replace the need for independent storage. This could be the case at Hibernia where offsite storage is under consideration and where STOLport operations offer the most scope..

Riser/anchor systems in use by exploration and storage vessels include the turret-mooring system and the single anchor leg system. In the former, the turret forms a moonpool through which the riser arrangement passes. In the single anchor leg system, the riser passes up through a single column which is connected by means of a universal joint to a base on the seabed. A yoke connects the bow of the vessel to the column through a gimbal and swivel arrangement which permits the vessel to weather-vane.

A major consideration when combining aircraft operations with oil storage on a single vessel is the risk of explosion and fire. Risk of fire can be greatly reduced by storing the oil in central



FLOATING STOLPORT CONCEPTS: TUNED BARGE

AND SEAFORTH MARITIME LIMITED

figure 7

tanks protected on all sides by water ballast tanks, particularly under the runway deck. The water ballast tanks also provide a double skin which protects against oil spill pollution in the event of collision damage. Ventilation of oil tanks would involve inert gas systems similar to those presently employed on oil tankers.

A barge configuration is more suited than the semi-submersible concept to conventional shipyard construction and is cheaper to build.

9.4 VLCC STOLport Barge

The possibility of reconfiguring, recombining and reinforcing the hulls of five surplus super tankers to form a STOLport barge was investigated. A possible layout for the reconfigured vessel is shown on Figure 8. At present, surplus oil super tankers (VLCC's) are available on the world market at between \$4 million to \$14 million (Canadian). While the scrapping of surplus tankers is proceeding at the rate of approximately 15 million dead weight tons annually, it is not likely that excess VLCC capacity will be eliminated before the end of the decade. However, if the concept is to be practical, there would have to be a reasonable dimensional and structural conformity between the five vessels to be joined. This will be increasingly difficult to achieve as the inventory of surplus vessels decreases.

In this concept, the required 602m long by 90m wide runway would be constructed atop a vessel that is 105m wide by 550m long fabricated from five VLCC hulls be cut into sections and reconnected end to end and side by side to form the STOLport vessel. The vessel, whose length would be approximately double the length of the original tankers would be reinforced with the additional steel plate on the bottom, sides and deck, so as to keep steel stress levels below their initial design values. The vessel could be anchored by a turret mooring system.

The runway would be of steel plate construction, elevated on supports. Its surface would be treated to improve traction. An arresting mechanism would be deck-mounted near the bow for emergency deployment. (This is a common requirement of all floating STOLport concepts.)

Navigational and other equipment would be provided and elevator platforms would be installed to transport aircraft, and mobile vehicles to hangars and maintenance bays below deck, where accommodations for crew, sick bay, storage and other services would also be located.

A brief review of tanker registries indicates that several similar vessels have been constructed, although a survey is required to determine their availability on the surplus market. The vessels would be reconfigured in drydock which could be a temporary facility constructed in Canada where stripping of surplus components would take place. Hull reinforcement, propulsion systems and dynamic positioning equipment would be added. The remaining work such as runway construction, piping and valving modifications, and the addition of hangars and the like could be completed at a fitting wharf.

The VLCC concept lends itself to accommodating crude oil storage facilities since tanks, piping and valving for water ballast and oil are inherent in the basic tanker design. The additional steel plate reinforcement required, to increase the bending capacity of the hull over the mid-section of the vessel together with additional stiffeners, could be added at appropriate locations to form water ballast tanks. Using the wing tanks for water ballast would allow the central oil storage tanks to be protected on all four sides. The hydrostatic pressure created by the surrounding ballast would inhibit oil leakage.

Oil storage available over the 150m length would be 223,000m³ cubic metres (1,750,000 barrels) with sufficient independent ballast capacity in the water tanks to obviate the need for a separating flexible membrane or water/oil separation facilities.

The central wing tanks could also be used for oil storage, in which case all capacity can be increased by 82,000 to 303,000m³ cubic metres (2,400,000 bbl.). Water ballast would have to be introduced into the wing tanks as oil unloading took place. Alternatively, additional steel reinforcement could be added to strengthen the vessels. Maximum oil storage capacity could be achieved by increasing the length of the oil tanks by adding additional steel to form the top and bottom water ballast tanks. The maximum practical capacity of the vessel would be approximately 450,000m³ (3.5 million barrels).

9.5 STOLport Barge Hydrodynamic Characteristics

The STOLport barge concepts under consideration had similar hydrodynamic characteristics with those of the tuned barge being somewhat superior. Its characteristics, shown in Table 13, are presented as being typical of the level performance that can be achieved with this type of vessel.

WAVE HEIGHT (m)	SURGE (m)	SWAY (m)	HEAVE (m)	ROLL (deg.)	PITCH (deg.)	YAW (deg.)
180 degree heading						
3	0.019	0.001	0.046	0.000	0.007	0.000
6	0.103	0.004	0.359	0.001	0.060	0.001
9	0.253	0.008	0.982	0.002	0.164	0.001
12	0.467	0.016	1.980	0.003	0.338	0.003
15	0.681	0.026	3.123	0.004	0.544	0.004
157.5 degree heading						
3	0.020	0.047	0.048	0.022	0.007	0.006
6	0.104	0.193	0.411	0.053	0.068	0.027
9	0.240	0.409	1.080	0.086	0.179	0.061
12	0.426	0.817	2.226	0.129	0.381	0.132
15	0.601	1.308	3.545	0.182	0.619	0.218

Table 12 STOLport Barge Significant Response Amplitude

The vertical velocity at the touchdown point is one component of the closing velocity of a landing aircraft on landing. The critical velocity, predicated by the design strength of the Dash-7 under carriage occurs at sea state 2 to corresponding wave heights 12 metres. Table 14 shows typical vertical velocities for the runway for various sea states.

WAVE HEIGHT	PERIOD	VERTICAL VELOCITY (m/sec.)	
		HEADING	
		180°	157.5°
3	6.0	0.065	0.074
6	8.0	0.443	0.510
9	9.5	1.024	1.131
12	11.0	1.812	2.054
15	12.0	2.657	3.020

Table 13 STOLport Barge Vertical Velocity at Touchdown Point

The percentage availability of the vessel for aircraft landings in significant waves of 10m and 11m is, for all three areas, ranges between 98 and 100 per cent. A breakdown of percentage availability for all three geographical areas is shown in Table 14. The availability of the VLCC STOLport barge would be marginally lower.

MONTH	NEWFOUNDLAND SHELF	LABRADOR SEA	SCOTIAN SHELF
January	99%	99%	98%
February	99%	100%	99%
March	99%	97%	98%
April	100%	100%	100%
May	100%	100%	100%
June	100%	100%	100%
July	100%	100%	100%
August	100%	100%	100%
September	100%	100%	99%
October	100%	99%	100%
November	100%	100%	100%
December	100%	98%	99%

Table 14 Percentage Availability of Vessel for Landing
(Significant wave height 10m & 11m)

Flying weather, rather than sea state appears to be the more significant factor limiting aircraft operations.

9.6 Evaluation of Alternative STOLports

9.6.1 System Definition

The principal criterion used for evaluating the STOLport options was cost, including total system capital and operating costs. These costs (in constant 1983 Canadian dollars) were calculated for passenger traffic volumes ranging from 25,000 annual, one-way person-trips to 300,000 annual, one-way person-trips for:

1. The Base Case, assuming rotary wing aircraft transport of personnel directly from the onshore base to the offshore platforms.
2. Floating STOLport systems, utilizing Dash-7 aircraft for the first stage transfer of personnel from the shore to a floating STOLport, followed by a shuttle service by helicopter or marine vessel, as the second stage of transfer, from the STOLport to the production platforms. The STOLport concepts evaluated were:
 - o Seaforth Maritime Semi-Submersible STOLport;
 - o Seaforth Maritime STOLport Barge or "Tuned Barge" with crude oil storage;
 - o VLCC STOLport Barge;
 - o VLCC STOLport-Crude Oil Storage Barge Combination.

Cost comparisons were made with base costs on basis of two assumptions:

- a) Gross costs for the STOLport system with no benefits attributed to crude oil storage;
- b) Net costs, which assumed full benefits from available crude storage.

9.6.2 Annual Fixed and Operating Costs

The relevant costs for the floating STOLport alternatives are summarized on Table 17 under the following headings:

- o Capital repayment and interest (interest 12%, repayment period 15 years);
- o Fixed overhead;
- o Fuel;
- o Crew requirements;
- o Aviation electronics.

ITEM	SEMI SUBMERSIBLE STOLPORT	STOLPORT BARGE	VLCC BARGE	VLCC BARGE (1.75mm bbl storage)	VLCC BARGE (3.5mm bbl storage)
Capital Cost	472	374	250	262	278
Annual Capital Recovery & Interest	68.9	54.8	36.5	38.2	40.6
Crew	7.1	7.1	7.1	7.1	7.1
Fuel	7.9	3.2	3.2	3.2	3.2
Maintenance	6.1	5.6	3.7	3.9	4.1
Insurance	2.0	1.9	1.3	1.3	1.4
Aviation Electronics	1.2	1.2	1.2	1.2	1.2
TOTAL	93.2	73.8	53.0	54.9	57.6

Table 15 Annual Capital and Operating Cost Summary
Floating STOLports
(\$ Millions Canadian 1983 annually)

The capital cost for the semi-submersible STULport was based on a 1981 cost estimate contained in a study by the Norwegian Ship Institute. Their estimates, converted to Canadian dollars at present rates ranged from \$200 million to \$414 million. The upper value increased to \$472 million (1983) dollars to allow for inflation, was used since it provided what judgementally appeared to be the appropriate cost differential over the STULport Barge concept. The capital costs for the other concepts were calculated independently as part of the current study.

9.6.3 Gross Cost Breakeven Traffic Levels

The breakeven points for each STULport system were defined as the level of annual person trips at which the unit transportation costs for each concept equalled the likely upper and lower person trip costs estimated for the Base Case. The break points for the STULport systems, excluding potential benefits from crude oil storage are shown on Figure 9 for the Hibernia zone. They are summarized for all three zones in Table 16.

SYSTEM	BASE	VLCC BARGE* NO STORAGE		SEAFORTH STULPORT BARGE		SEAFORTH SEMI- SUBMERSIBLE STULPORT	
		UPPER BASE CASE COST	LOWER BASE CASE COST	UPPER BASE CASE COST	LOWER BASE CASE COST	UPPER BASE CASE COST	LOWER BASE CASE COST
Hibernia	St. John's	160,000	210,000	205,000	260,000	260,000	325,000
Scotian Shelf	Halifax	205,000	260,000	300,000	**	**	**
	Halifax/ Sydney	180,000	255,000	245,000	**	325,000	**
	Halifax/ Sydney/ Yarmouth	145,000	170,000	125,000	255,000	260,000	325,000
Labrador	Hopedale	**	**	**	**	**	**
	Cartwright	270,000	**	**	**	**	**

Table 16 STULport Comparison (basis Gross Costs Hibernia)

* VLCC barge with storage would break even within a range level of 30,000 person trips above VLCC barge no storage

** break points beyond upper level of study traffic range.

9.6.4 Breakeven Traffic Levels - Net of Oil Storage Costs

The three STOLport concepts with crude oil storage capacities of 1.75 mm bbl, 3.5 mm bbl. and 4.3 mm bbl. capacities were evaluated on a net cost basis for the Hibernia site only. The costs were arrived at by reducing the gross annual standby and operating costs for the VLCC combined storage STOLport Barge concepts and the Seaforth Maritime Barge STOLport by the estimated cost of providing equivalent storage separately, or \$9.30 per barrel of available storage annually. The resulting net STOLport system costs shown in Figure 9. The traffic levels at which each alternate STOLport would provide the same unit cost of service as the Base Case is shown in Table 17:

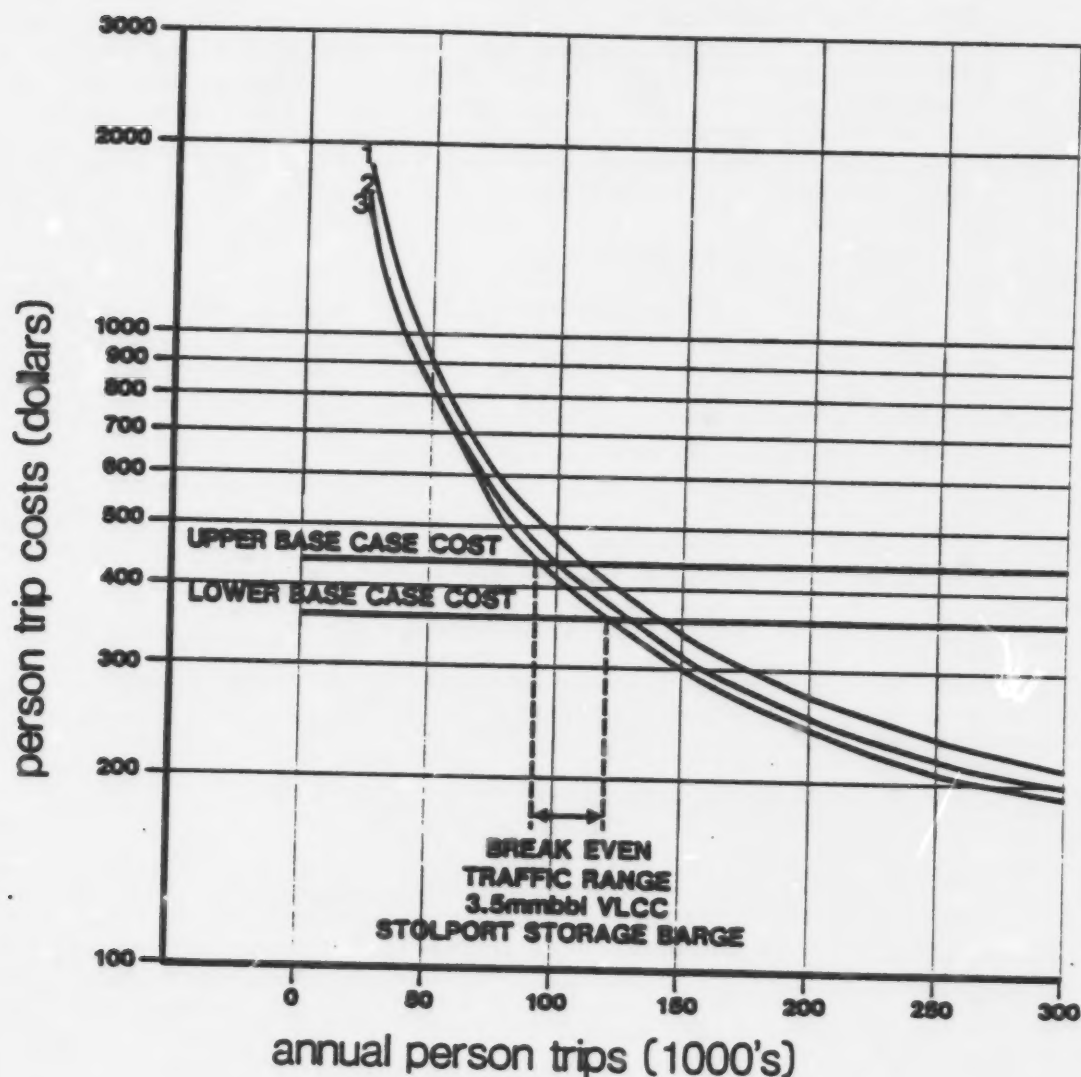
	BREAK EVEN POINT (PERSON TRIPS ANNUALLY)		
	1.75 mm bbl STORAGE	3.5 mm bbl STORAGE	4.3 mm bbl STORAGE
	VLCC BARGE	VLCC BARGE	SEAFORTH MARITIME STANDARD BARGE
Upper Base Case Cost	110,000	90,000	97,000
Lower Base Case Cost	137,000	120,000	125,000

Table 17 Breakeven Traffic Levels STOLport Storage Barge Concepts (Net Hibernia)

10. DEVELOPMENT IMPLICATIONS

10.1 Rotary Wing Aircraft

The forecast level of helicopter operations off Canada's east coast does not by itself appear to justify development of new basic helicopter technology in Canada. Indeed, because of the high development costs involved relative to the potential for improvement, new, basic equipment in U.S. and Europe will likely only be developed as part of military programs. None of the



- 1 VLCC STOLPORT BARGE (1.75mmmbbl storage)
- 2 SEAFORTH MARITIME STOLPORT BARGE (4.3mmmbbl storage)
- 3 VLCC STOLPORT BARGE (3.5mmmbbl storage)

STOLPORT STORAGE BARGES net systems cost comparisons

EN Group

figure 9

advanced equipment concepts examined appear to offer major scope for radical operational changes or for significantly improving economies from those currently experienced with existing aircraft within the timeframe of this study. There is, however, considerable scope for the improvement of helicopter reliability and safety through the development of special purpose systems in such areas as ice detection, air to ground communications, landing aids and en route nav aids. Canadian industry already has a strong capability in these areas and through further aggressive marketing could increase its market share.

10.2 Floating Heliports

The study could not substantiate the economic viability of the new special purpose heliports considered. The alternative of a two stage shuttle, involving transfer of passengers at a off-shore heliport from large to smaller helicopters does not offer significant economic benefits because the potential cost savings in the long haul leg are generally more than offset by the capital and operating costs incurred by the floating heliport facilities and the offshore shuttle service necessary to connect to the platform. There is also loss of time involved in the transferring of passengers between the en route and shuttle helicopters.

While not specifically falling within the scope of the study, the possibility of using a floating heliport as a forward service base for providing support services under both normal and emergency conditions was identified. This concept deserves further consideration.

10.3 Floating STOLports

Floating STOLport concepts which can also provide crude oil storage could be economic at the upper level of the current traffic forecast range for Hibernia depending upon the level of shared benefits assumed for the available crude oil storage capability. It is technically feasible to construct such vessels having the necessary size and stability to accommodate highly reliable Dash-7 operations.

The drydocks and supporting infrastructure required to construct floating STOLports do not exist in Canada, and the construction of a temporary drydock coupled with other costs associated with Canadian shipbuilding will increase overall costs by approximately 20% for the converted VLCC STOLport barge concept. The additional costs for the more sophisticated concepts would be proportionately greater. Construction of an all new vessel such as the Seaforth Maritime STOLport barge might be feasible in Canada but it would have to be constructed in modules joined together for completion.

The floating STOLport barge concept is recommended for study by government and industry as it appears to offer considerable scope for reducing transportation costs, and for improved reliability, comfort and convenience in the offshore air transportation system. Implicit in this solution, are very significant potential economic benefits to Canada resulting from the manufacture of Dash-7 aircraft to support resource development.

10.4 Landing Systems

Category III landings at floating STOLports and heliports appear feasible, however, the limited weather data available to the study did not permit a precise assessment of potential benefits. Given that Category II limits control at Hibernia, air operations could be at a standstill 13% of the time on an annual basis. The Dash-7 does not have the necessary auto pilot and control systems for fully automatic Category III landings, but the potential benefits attainable from operating at reduced limits appear to justify examining the problems involved in upgrading the aircraft in this respect. The undertaking of such an evaluation would be dependent upon a favourable reaction by the oil industry to the prospects for offshore STOLport operations.

Development of systems to permit Category III landings by helicopters is underway but such operations may be precluded at offshore platforms because of intrusion of platform superstructures into the approach airspace.

10.5 Special Purpose Marine Vessels

Vessels of the semi-submersible catamaran type could provide a viable substitute to the second stage offshore helicopter shuttle, that would otherwise be required with either floating heliports or STOLports. Based on a system-to-system comparison, excluding the cost of weather-related delays, the breakeven traffic level between semi-submersible vessel relative to helicopter operations appear to be approximately 100,000 person trips annually.

While it was outside the scope of this study to examine marine transport problems, the semi-submersible hull vessels appear to offer significant advantages over conventional vessels for operating in heavy seas. Their surge/heave characteristics can closely match those of semi-submersible platforms thereby facilitating passenger transfer during high sea states but the effects of ice build-up require further research in the context of the Canadian east coast environment. There may also be opportunities for manufacturing of or producing components of such vessels in Canada.

10.6 Offshore Fixed Airports and Heliports

The cost of developing the Virgin Rocks site as an offshore heliport does not appear to be economically justifiable. If the site was developed for other uses, the inclusion of heliport facilities would provide benefits to the offshore aviation industry particularly if the heliport could be designated as an IFR alternate.

The development of a STOLport at Sable Island could result in significant operating benefits to offshore aviation and resource industries. It could be a cost-effective solution for the Venture field and, therefore, its feasibility in both economic and environmental terms should be examined.

10.7 Controlled Facilities and Infrastructure

Requirements for centralized government operated facilities in the areas of communication, en route navigation, law enforcement, safety services, general administration and control will increase as the level of offshore activities grow. Such requirements individually will not significantly effect the economics of any of the concepts researched in this project, however, the opportunities for providing such facilities in larger centralized structures where costs might be shared with the oil industry should be considered on an on-going basis.

10.8 Floatel Facilities

The North Sea experience indicates a continuing requirement for offshore work platforms housing up to 500 workers for the construction of production platforms (floatels). Such requirements have not been identified for Canada's east coast. Should such facilities prove to be necessary, combining them with a floating STOLport could tip the economic balance in favour of fixed wing aircraft operations. The requirements for floatel facilities should be monitored by industry and government, and should the current view change, the viability of the semi-submersible STOLport concept should be reassessed.

11. MAJOR CONCLUSIONS AND RECOMMENDATIONS

Canada's east coast offshore petroleum resource recovery operations can be considered to be in their infancy and therefore the scale of future production cannot be precisely established for

the longer term. All of the floating STOLport concepts examined in this study could be economically justified at employment levels approximately 2.5 times those contained in the current maximum forecast. The floating STOLport barge concepts are only marginally uneconomic for the Hibernia field at the upper employment level forecasts. If the crude oil storage capability of the barge concepts could be effectively utilized, these concepts could be economic at below the upper forecast employment level. This is an area for further consultation with the oil industry. Monitoring the need to carry out more detailed studies on this concept is the major recommendation of this study.

New special purpose floating heliports, while offering the potential for improved service reliability cannot be justified on economic grounds only. However, conversion of existing offshore floating structures for use as IFR alternate heliports appears feasible and potentially attractive as a relatively low-cost means of providing a forward base to support a variety of industry/government agencies. The Government should consider examining the operating implications, design requirements and standards for such facilities in order to be in a position to provide advice and support to the offshore aviation and oil industries.

The format of the offshore weather data bank does not readily lend itself to aviation weather analysis to the required level of detail. Consideration should be given to expanding the capability of AES to gather data in more directly applicable formats and with the necessary correlation between atmosphere and sea state conditions. These requirements should be addressed on a priority basis.

Air traffic in support of east coast energy resource recovery will increase more rapidly than will on-shore scheduled and general aviation traffic particularly if helicopters remain the only air mode. This will increase the pressure on the Government to provide levels of air traffic control service and telecommunications facilities more in keeping with its onshore standards and responsibilities.

A number of potential areas for Canada's involvement in the production of air transportation facilities and equipment for offshore operations were identified. These include:

- o Avionics and ice detection systems for helicopters
- o Special purpose navigation and communications systems
- o Floating STOLport components of the floating barge type
- o STOL aircraft design and manufacture.

The potential for exporting technology resulting from transportation equipment development would be greatest in the areas of avionics, aircraft, offshore communications and nav aids.

The Hibernia area offers a good testing ground for equipment both because of its remoteness from land and because of the harsh marine and weather operating environment.

Implementation of the STOLport concept would increase the opportunities for the export of Dash-7 aircraft, but exports of floating STOLports does not appear to be likely primarily because of high Canadian ship building costs.

The tilt rotor/wing aircraft, is technically exciting, and if further developed and certified for civilian use it could play a role in offshore transportation in the longer term.

Although outside the scope of this study, the catamaran semi-submersible marine vessel appears to have good motion/reliability characteristics, and warrants further study, both in terms of its utilization for east coast transportation and as a possible product for Canadian manufacture.

OFFSHORE AIRPORT CONCEPTS
SERVICING THE EAST COAST ENERGY RESOURCE INDUSTRY

MAIN REPORT

by

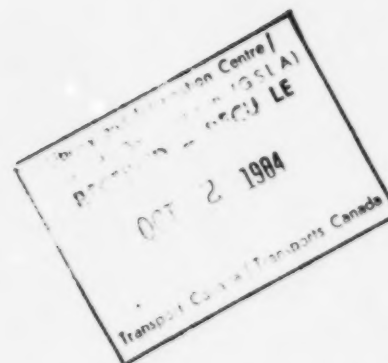
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The contents of this report reflect the opinions of the Consultant and are not to be construed as the official policy of the Transportation Development Centre.

Dimensions and measurements contained in this report may appear in both imperial and metric quantities as a reflection of common usage and standard practice of the aviation and marine industries.

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17. Resume La mise en valeur des ressources énergétiques au large des côtes Est du Canada nécessite le transport d'effectifs à des distances pouvant atteindre 200 milles marins, dans des conditions climatiques extrêmement rigoureuses. Trois secteurs ont été étudiés: la mer du Labrador, Hibernia et le plateau continental près de la Nouvelle-Ecosse, et les exigences correspondantes déterminées du point de vue logistique, environnement, sécurité, réglementation et infrastructure, ainsi que l'utilisation d'ADAC. Le rapport détermine les états de mer et les conditions climatiques et glaciales auxquels il faut faire face. Il présente un devis des dépenses d'investissement et des coûts d'exploitation concernant les plates-formes d'atterrissage tant fixes que flottantes, utilisées comme base avancée soit par des hélicoptères, soit par des ADAC du type DASH-7. Le coût global du concept étudié est comparé à celui du concept de base faisant appel à des hélicoptères basés à terre. Aucun des concepts de plate-forme marine étudiée ne semble pouvoir apporter des économies suffisantes pour amortir les dépenses d'investissement initiales, du moins aux niveaux de trafic couramment prévus. Le coût d'héliports ancrés peut aller jusqu'à 590 millions de dollars, celui d'adacports flottants varie entre 250 et 472 millions et celui d'héliports flottants entre 42 et 110 millions. Néanmoins, l'idée de prévoir des réservoirs de pétrole brut dans l'enceinte d'un adacport flottant pourrait réduire appréciablement le niveau de trafic minimal justifiant les investissements à consentir.		13. Genre de rapport et période visée Août 82-Décembre 83
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A multi-disciplinary steering committee under the direction of the Transportation Development Centre was established to promote active participation and information exchange within government organizations, aviation and marine communities, and the petroleum industry.

PREFACE

This document describes research undertaken to identify and investigate feasible air transportation options for the support of offshore energy resource development in Eastern Canada.

Primarily concerned with the handling of passenger traffic, the objectives of this project were to identify and evaluate:

- o the opportunities for improved air transportation technology involving rotary winged aircraft and heliport facilities; Short Take Off and Landing (STOL) operations; artificial islands; SWATH personnel carriers; semi submersible hulls; tuned barges; associated navigational aids, and traffic control mechanisms, in support of offshore drilling operations.
- o the technical and economic feasibility of a floating airport and related technology for Canada.
- o the opportunities in Canada for high technology export or for internal self sufficiency and growth.

The following activities were carried out in order to achieve the objectives proposed.

- o Reviews and assessment of:
 - existing offshore resource development scenarios in Eastern Canada, and the modes of transportation currently employed
 - offshore energy resource development practices in the North Sea, for comparison purposes
 - demand forecasts for future offshore development
 - logistical requirements
 - state of the art technology for aviation, relating to rotary winged and fixed wing aircraft, Short Take-Off and Landing (STOL) aircraft and associated navigational aids
 - state of the art technology for marine architecture such as semi-submersible vessels and artificial islands
 - offshore aviation facilities standards
 - climatic information
 - certification and regulatory considerations.
- o Development of a series of Working Papers and analytical models to describe, analyze and evaluate the existing situation and the opportunities for improvement.
- o Preparation of summary report to document the results of the project work and provide a basis for possible implementation of the opportunities.

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1.0 INTRODUCTION

Offshore Airport Concepts Servicing the East Coast Energy Resource Industry documents investigations into the feasibility of optional air transportation modes in support of offshore energy resource development in Eastern Canada.

1.1 Background

The increasing demand for a secure supply of petroleum for export and the drive towards Canadian energy self-sufficiency has in recent years shifted the focus of hydrocarbon energy exploration and development in Canada from the mainland to offshore areas. It has resulted in the development of offshore resources which had previously been considered uneconomic, and has encouraged the development of new exploration technology which permits drilling to greater depths and at greater distances from land. Highly successful demonstrations of deep sea production technology exist in the North Sea where major petroleum discoveries are being successfully exploited. Experience gained here and elsewhere has assisted in the development of offshore drilling technology and resource recovery in eastern Canada where development drilling is progressively locating to deeper water and to more remote sites exceeding 200 nautical miles from shore.

While oil field logistics in Canadian frontier areas, are heavily influenced by experience gained in other offshore areas, this study demonstrates that local environmental and other considerations are sufficiently different from those prevailing elsewhere to warrant giving consideration to the development of more site specific solutions. Also, that there is scope for the development of unique solutions of particular benefit to Canada, especially if development activity levels were to exceed current expectations.

Aviation continues to play a key role in these activities. Heavy demands are being made on fixed wing aircraft to serve the onshore supply

bases and on rotary wing aircraft, to link the offshore rigs to the on-shore supply depots. With the continuing increase in flying distances and traffic demands concern is being expressed regarding the capability of rotary wing aircraft to meet the future requirements for resupply purposes. Most rotary wing aircraft currently in operation have limitations relative to their offshore support role in terms of range, economics, comfort and in some situations safety. Technological advances in these areas could greatly improve their role as a primary mode of transport. Intermediate capacity fixed wing aircraft with STOL capability present another option for service improvement, because of their greater payload capacity, range and lower operating costs.

The introduction of floating heliports, artificial islands or floating STOLport concepts provide potential for more effective rotary wing aircraft operations. The service response of helicopters would be enhanced by the introduction of a floating heliport, or fixed heliport atop an artificial island since such solutions would make it more practical to install improved air navigation and landing aids. The implementation of a floating STOLport would permit utilization of STOL aircraft to provide the trunk service augmented by helicopter links to individual platforms. The STOLport has further potential benefits of being able to accommodate a wide range of support facilities and activities such as crew accommodations, meteorological observations, air traffic control facilities and search and rescue functions.

Another concern of the offshore petroleum industry is the requirement for improved meteorological, and air traffic control and telecommunications services at offshore locations. Increased air traffic volumes resulting from the forecast growth in offshore activities will reinforce the requirement for standard pilot flight briefings, weather information, navigation facilities and air traffic control for offshore applications.

Current indications are that development of offshore energy resources will continue, probably resulting in drilling operations at progressively greater distances from land. This will in turn place an increased strain on the capabilities of the transportation system now in place.

This report describes the technical and regulatory problems associated with the transportation related logistics of hydrocarbon resource exploration and recovery; and examines the feasibility of a number of unproven concepts for transportation improvement. It is hoped that the development and subsequent implementation in whole or in part, of any of the innovative concepts examined in this study will contribute to the economic well being of the country by assisting in the achievement of national goals including:

- o attaining energy self-sufficiency
- o job creation in Canada
- o developing new products or technology for export.

1.2 Scope of the Project

The scope of the research project included full consideration of geographical and environmental factors affecting transportation between onshore and offshore locations along the east coast; state of the art technology for aircraft and marine vessels suitable for adaptation to offshore development resupply requirements; and present and future transportation requirements of the petroleum industry.

Although the primary aim of the research was to evaluate options pertaining to effective passenger transfer, secondary benefits such as Canadian content and possible economic spin offs were identified.

The research is described in this final report which is divided into three major parts as follows:

- o Section 1 outlines the basic objectives and scope of the study, and describes the methodology employed;
- o Sections 2 to 9 present information relating to the geographical features of the areas under consideration, the operating environment, resupply logistical requirements, aircraft and vessel design and performance characteristics, and form the basis for subsequent system evaluations, and;
- o Sections 10 to 12 outline the systems analyses and evaluations, and contain recommendations for the future development of the preferred concepts.

1.3 Project Methodology

The following methodology was employed to achieve the objectives of the research project.

- o A detailed review of background information was completed to ensure comprehensiveness. The following topics were researched:
 - the geography of the selected study locations, including environmental considerations;
 - the existing scenario for energy resource development on the east coast of Canada;
 - demand forecasts for future offshore development;
 - logistical problems associated with transporting passengers and cargo to drilling platforms operating in deeper water, further from the mainland;
 - state of the art technology for aircraft with short take-off and landing (STOL) capability;

- opportunities for technological improvements based on STOL concepts;
 - associated navigational aid requirements;
 - state of the art technology for marine craft such as a floating airport capable of accommodating STOL type aircraft as well as support systems, crew accommodation and hydrocarbon storage;
 - state of the art technology related to rotary wing aircraft design and operations, including potential for improved performance and safety;
 - certification, regulatory and safety requirements.
- o A study design report was developed to detail the scope of the project and formally document the tasks to be accomplished. The report was prepared on the basis of preliminary assessment of problem areas and potential solutions, in the interests of concentrating research efforts.
 - o A series of Working Papers were prepared to determine the suitability of a maritime heliport, STOLport, or artificial island in the Canadian context by:
 - assessing the capability of rotary winged and fixed wing STOL craft to meet the ongoing transportation needs of offshore petroleum drilling operations;
 - assessing the capability and operational reliability of the floating STOLport under various climatic conditions;
 - assessing the capability of the Dash-7 STOL aircraft to operate safely within the context of existing Transport Canada air navigation regulations;
 - assessing the applicability of existing Transport Canada standards and regulations relating to air navigation and offshore STOLports;
 - assessing the economic advantages to Canada through the development of a floating STOLport technology; revision of air navigation regulations; technological improvements to rotary-winged and STOL aircraft; improved procurement of energy resources, and progress in safety and living conditions.

Evaluations of the effect of climatic factors on system availability, payload transfer logistics, vessel performance and aircraft traffic volumes were performed with the assistance of manual and computer simulation models, in some cases specially developed to meet the requirements of this project.

2.0 LOCATION

2.1 Study Site Selection

The three major Canadian east coast offshore areas currently being explored and assessed for petroleum production are offshore Labrador (Labrador Sea), offshore Newfoundland (Hibernia) and offshore Nova Scotia (Scotian Shelf). Federal and Provincial permits were approximately 110,000, 158,000 and 205,000 square kilometres within these three zones respectively.

In order to structure the research, the decision was made to identify a finite representative area within each of the three geological zones, upon which to base the analysis. In each zone, a representative site having a radius of approximately 50 nautical miles (approximately 10,000 sq.km) was selected and the associated main on shore supply base identified. The three sites chosen were: a zone centered approximately 100 nm east of Hopedale, Labrador (Labrador Sea Area), another centered 205 nm east of St. John's, Newfoundland (near the Hibernia Field) and the third located 160 nm east of Halifax, centered on Sable Island (Scotian Shelf). The selected areas are shown on Figure 1.

All three areas are currently the focus of intensive exploration, and represent the most likely offshore production zones for the respective geographical areas. They do not, however, represent the extreme location in terms of helicopter logistics, a factor addressed in the sensitivity analysis, carried out as part of the overall systems analysis.

2.2 Location

Each selected study area represents an offshore/onshore system which includes common elements such as:

- o climate;
- o an offshore destination;



DISTANCE BY AIR Scotian Shelf

Halifax-Sable	160 nm
Sydney-Sable	133 nm
Yarmouth-Sable	223 nm

Newfoundland Shelf

St. John's-Hibernia	204 nm
Gander-Hibernia	290 nm

Labrador Sea

Goose Bay-Labrador Sea	187 nm
Hopedale-Labrador Sea	100 nm
Cartwright-Labrador Sea	138 nm

DISTANCE BY LAND

Halifax-Yarmouth	321 km
Halifax-Sydney	432 km
St. John's-Gander	331 km
St. John's-Argentia	131 km
Goose Bay-Cartwright	210 km
Goose Bay-Hopedale	250 km

IBI GROUP

EXPLORATION AREAS

figure 1

- o a land-based airport, in close proximity, acting as a primary supply centre;
- o alternate landside airports.

The three geographically selected systems are defined in Table 1

STUDY AREA	LOCATION	CENTERED AT	PRIMARY SUPPLY BASE	ALTERNATE AIRPORTS
The Scotian Shelf	41°N - 47°N 50°W - 67.5°W	Sable Island	Halifax, Nova Scotia	Sydney, Yarmouth, Nova Scotia
The Newfoundland Shelf	46°N - 53.5°N 46°W - 54.5°W	Hibernia 47.5°N 47.5°W	St. John's, Newfoundland	Gander, Newfoundland
The Labrador Sea	52°N - 62°N 53.5°W - 64°W	Labrador Sea 57°N 57.5°W	St. John's, Newfoundland (Cartwright, Hopedale)	Cartwright, Goose Bay, Hopedale, Newfoundland

Offshore Development Zone Location

Table 1

2.3 Distances By Air

Distances by air between offshore destinations and corresponding land-side bases are shown in Table 2. The primary flying stage lengths range from 100 n.m. (Cartwright to Labrador Sea) to 204 n.m. (St. John to Hibernia). The maximum flying distance from an offshore site to an I.F.R. alternate airport is 290 n.m. (Hibernia - Gander).

<u>Scotian Shelf</u>	
Halifax - Sable	160 nm
Sydney - Sable	133 nm
Yarmouth - Sable	223 nm
<u>Newfoundland Shelf</u>	
St. John's - Hibernia	204 nm
Gander - Hibernia	290 nm
<u>Labrador Sea</u>	
Goose Bay - Labrador Sea	187 nm
Hopedale - Labrador Sea	100 nm
Cartwright - Labrador Sea	138 nm
St. John's - Labrador Sea	

Flying Distances

Table 2

2.4 Distances by Land

The overland distances between land bases are shown in Table 3.

<u>Scotian Shelf</u>	
Halifax - Yarmouth	321 km
Halifax - Sydney	432 km
<u>Newfoundland Shelf</u>	
St. John's - Gander	331 km
St. John's - Argentia	131 km
<u>Labrador Sea</u>	
Goose Bay - Cartwright (no permanent road link to date)	210 km
Goose Bay - Hopedale	250 km

Land distances Between Airports

Table 3

2.5 Aviation System Implications

A key factor in the comparison of the aviation systems considered in the study is the payload/range characteristics of the specific aircraft selected for study purposes. The passenger per mile cost of the Dash-7 STOL aircraft is relatively constant over the flying distances considered in the study, and, therefore, its unit operating costs are highly sensitive to the precise location of the selected study sites within each of the three geographic zones.

All three study sites involve distances within the IFR operating range of the helicopters selected for study purposes, however, these helicopters, with the exception of the Boeing BV234LR, are restricted in payload for flights to the Hibernia field due to range. Some helicopters would experience payload reduction to the Section Shelf as well.

The required operating range of the aircraft is predicated by the requirement that under IFR operating rules the aircraft must be capable to flying to its destination, and then, without touchdown or refueling, be capable of reaching, with adequate fuel reserves a designated IFR alternate land based airport.

The Labrador and Scotian Shelf exploration zones roughly parallel their respective coast lines, therefore, the flying distances from existing or possibly future heliports on the mainland to offshore zones are not highly sensitive to assumed study site location. In the case of the Hibernia field, however, the choice of main base and alternate airport is restricted. If development were to proceed to the east of the assumed study site, the payload restriction assumed for rotary winged aircraft operations in this system would be increased, resulting in a greater need for improved offshore based airports and heliports. These considerations were taken into account during the study as part of a sensitivity analysis.

3.0 OPERATING ENVIRONMENT

3.1 Scope

This section on operating environment describes the effects of weather and sea state on activities relating to the transfer of crews and cargo. Details on

- o air temperatures
- o windspeeds
- o precipitation
- o freezing spray potential
- o visibility
- o ceiling
- o windchill
- o wave height, frequency and duration
- o sea ice and
- o iceberg drift

were examined in combination to develop a climate profile for offshore sites, which formed the basis for assessing the technical feasibility, decision requirements and the operational limitations of the alternative systems concepts which were involved. Research into meteorological records uncovered the requirement for more comprehensive weather reporting suitable for use in air navigation to offshore locations. Reliable historical data on wave heights and storm events is lacking but reliable information is becoming increasingly available. Because of the lack of hourly information on ceiling and horizontal visibility conditions at offshore locations, diurnal patterns were simulated using aggregate data from each offshore locations and patterns from the nearest applicable land based weather station.

3.2 Availability of Climate Data

Climate data was obtained from the computerized data bank of Environment Canada at their Canadian Climate Centre Atmospheric Environment Services (AES). Information on various elements such as wind speed, air temperature, precipitation, ceiling height and wave characteristics was obtained from published information and retrieved by routine automated data retrieval from the AES data base.

Information provided through the use of this data bank was extensive in a historical context but had limitations for aviation use. Data on wave extremes and other meteorological conditions is supplied to AES by the Departments of National Defense, and Fisheries and Oceans. Raw meteorological data for landside sites is routinely compiled by well-trained AES staff who tabulate observations on an hourly basis in accordance with standard procedures. For offshore climatic information, the Department relies on the efforts of less qualified, international ship or offshore oil rig crews. These measurements are taken irregularly, or every six, eight, twelve or twenty-four hours, thereby representing a lower quality product. Storm information involving wave heights and visibility ratings are at times incomplete or less accurate since ships try to skirt bad weather. Rigs are, however, moored for the season and crews can provide a continuous and accurate information. Such historical data is incomplete, however, due to the seasonal nature of drilling and the relocation of rigs; or it is unavailable due to the recent emergence of the industry on the east coast.

To overcome this problem, raw data, in certain instances, has been modified or simulated where necessary. The methodology employed in such cases is described under the appropriate section.

In the case of the Sable Island offshore location, the climatic data obtained from the AES data bank was used since it differed from that published for the Island based weather station.

The offshore climate is characteristically harsh and sometimes subject to rapidly changing conditions. Although air temperatures are relatively mild in comparison to other regions in Canada, the influence of strong winds results in windchill and freezing sea spray, two undesirable conditions for operations on deck. The seasonal presence of sea ice, drifting icebergs and extreme sea states endangers moored vessels; while frequent periods of fog or low ceiling hamper aircraft movements.

Environment Canada has recently announced that it intends to purchase additional aircraft and advanced sensing equipment for improvements to its ice patrol. The patrol coverage is to be extended by roughly 500,000 square kilometres, and with the new sensing equipment, night sensing will be possible -- a key function considering the long periods of nighttime visibility associated with the long northern winters. It is anticipated that the data to be collected will assist in the understanding of iceberg development and ice pack movement, information that will prove valuable to offshore development.

3.3 Aviation Weather

Generally speaking, approximately 20% of all aircraft accidents (world-wide) are weather related, with twice as many mishaps occurring during take-off and landing as en route¹. This rate has apparently remained unchanged during the last ten years despite more sophisticated aircraft operating procedures and sensing devices.

Not only is weather a concern from a safety standpoint, but it is becoming increasingly important in the economics of flight scheduling. Additional fuel reserves, necessary for flights anticipating strong headwinds, and scheduling uncertainties during marginal visibility conditions result in higher operating costs, as do aircraft crew standby expenses, additional payments in the form of overtime charges, living

¹ Schwarz, U., ICAO Bulletin, Vol. 38, No. 5, Montreal, May, 1983.

expenses, and other standby costs for offshore workers. Likewise, delays in exchanging rig workers results in additional costs to oil companies for overtime changes and living expenses, for those awaiting transfer from landside bases.

For the purposes of air navigation, these aspects of climate are ranked in order of significance and described in the following sections:

- o visibility, fog, low cloud
- o wind
- o rain, freezing precipitation
- o icing
- o snow

The available weather information, in standard aviation format was obtained from official Government of Canada publications. However, information, particularly diurnal visibility data in the required detail and format, was not available for the offshore locations. Minimal visibility charts were generated for each of three offshore sites by a simulation process reconfiguring the available coarsely aggregated offshore data into an hourly format by an analogous procedure using visibility charts from adjacent land-based airports, (including the Sable Island weather Station) as the base for each system.

3.3.1 Visibility

The principle climatological factor affecting air navigation within the geographical systems under study is visibility. Figures 2 to 11 display visibility probabilities plotted on an hourly basis, as a product of ceiling height and horizontal visibility for Visual Flight Rules (VFR), Instrument Flight Rules (IFR) Categories I and II.

The following landing minima were utilized to classify weather data for this report.

Operating Conditions	Minimum Decision Height(m)	Minimum horizontal Visibility or Primary Visual Range(m)
VFR	300	4800
IFR Category I	60	800
II	30	400
III(a)	0	200
III(b)	0	50
III(c)	0	0

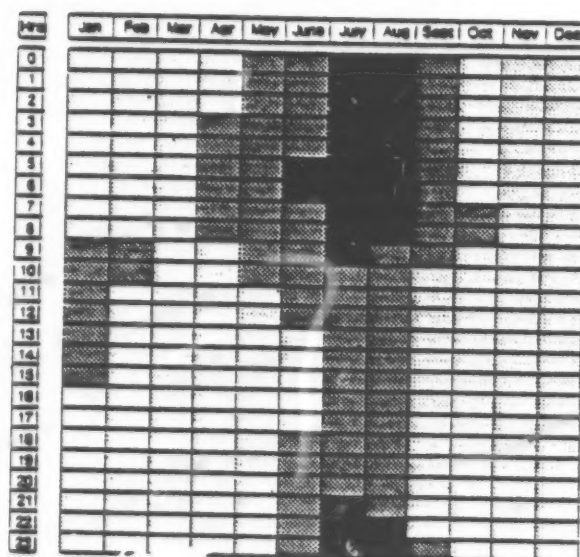
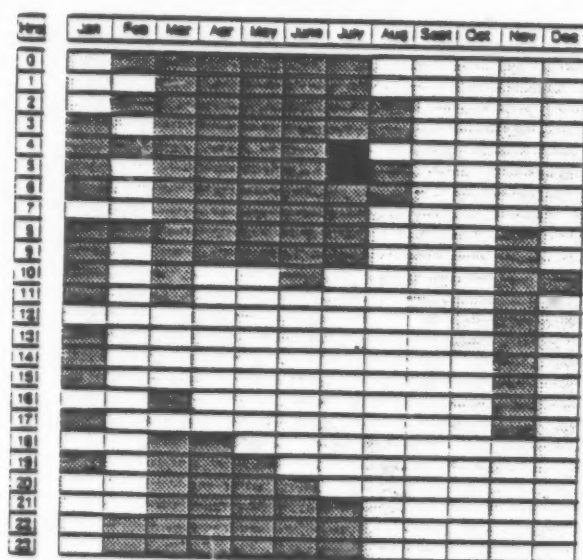
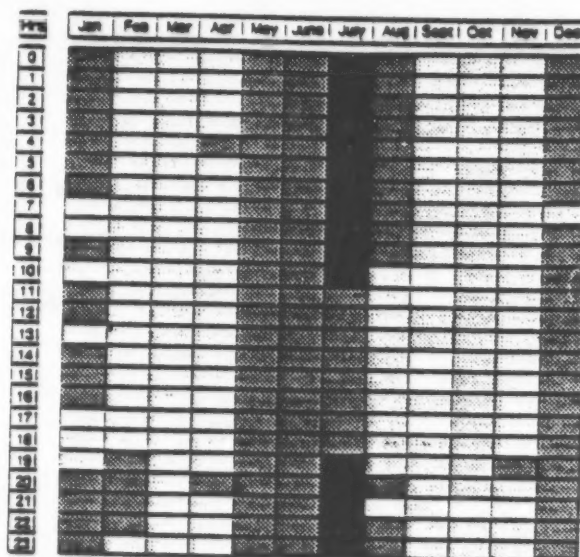
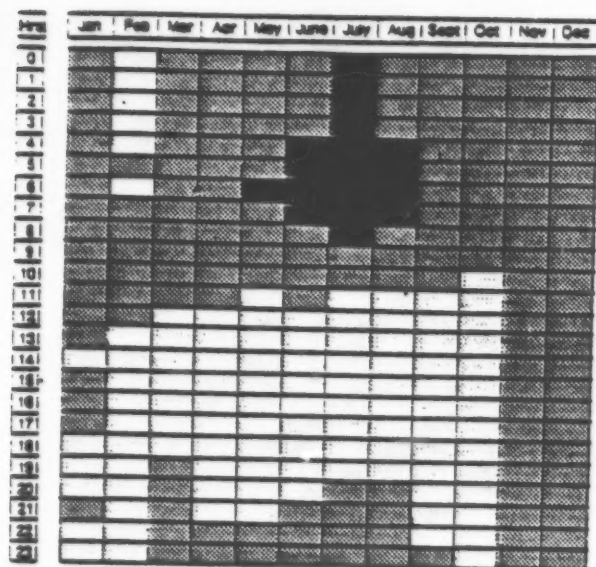
Operating Minima²

Table 4

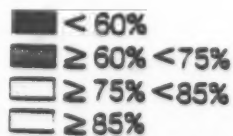
Unshaded squares in the figures indicate periods of optimal visibility, while darkened blocks represent intervals of reduced visibility caused by fog or other events other than darkness. Legends identifying percentage occurrences within IFR conditions have been assigned a dissimilar scale to that of VFR to allow for more precise interpretation.

When considering a flight between offshore sites and the mainland, conditions within the entire geographical system are to be taken into account. Visibility is usually less favourable at offshore locations, so the decision to stage a flight is generally influenced by the weather situation at the offshore heliport, STOLport or rig location rather than by landside considerations.

² International Civil Aviation Organization. International Standards and Recommended Practices. Aerodromes. Annex 14 to the Convention on International Civil Aviation, Montreal, 1976.

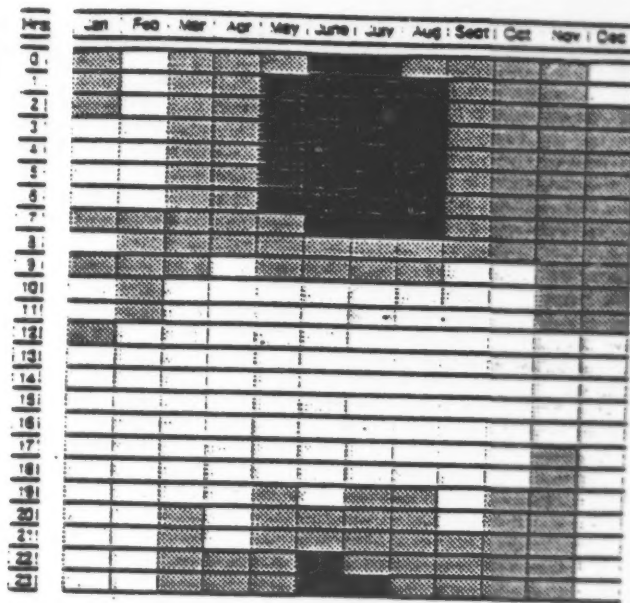


Percent Frequency of Ceiling > 300m and Visibility > 4800m

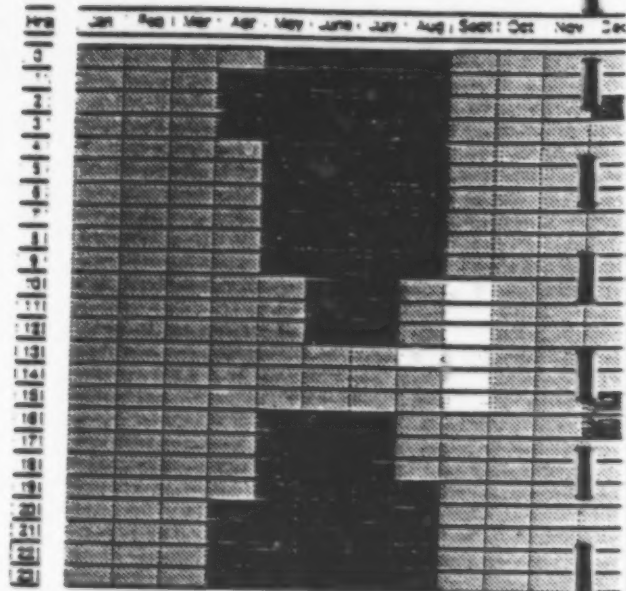


SABLE ISLAND -VFR
offshore airport alternative

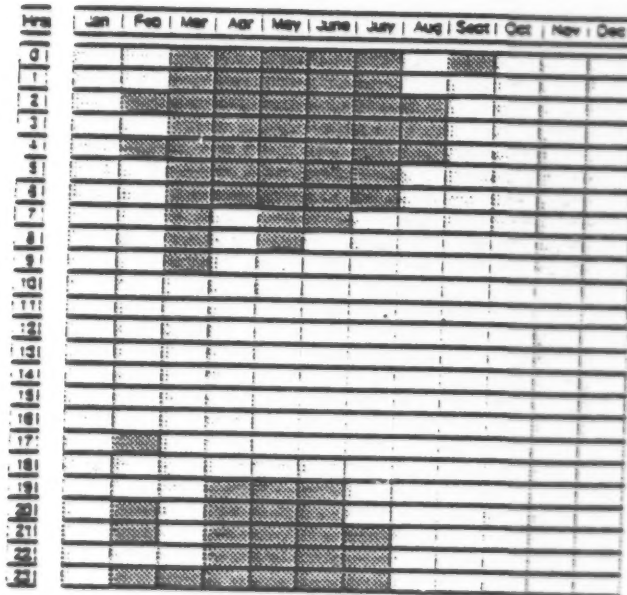
figure 2



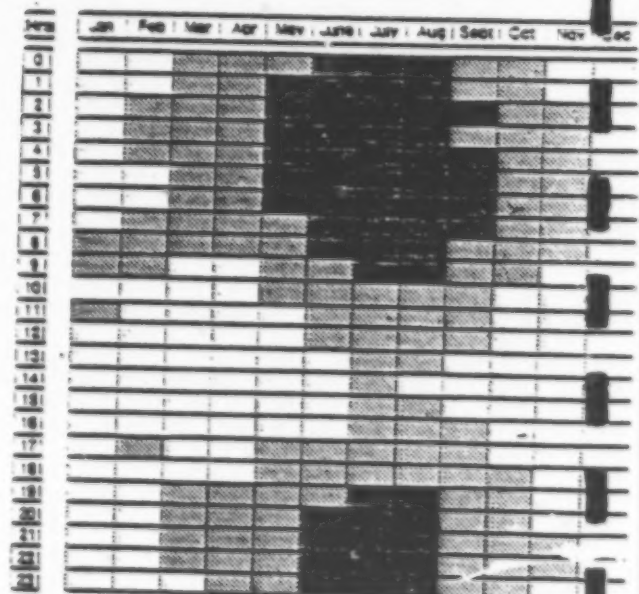
Halifax



Sable Island - offshore (simulated)

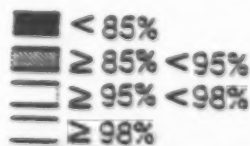


Sydney



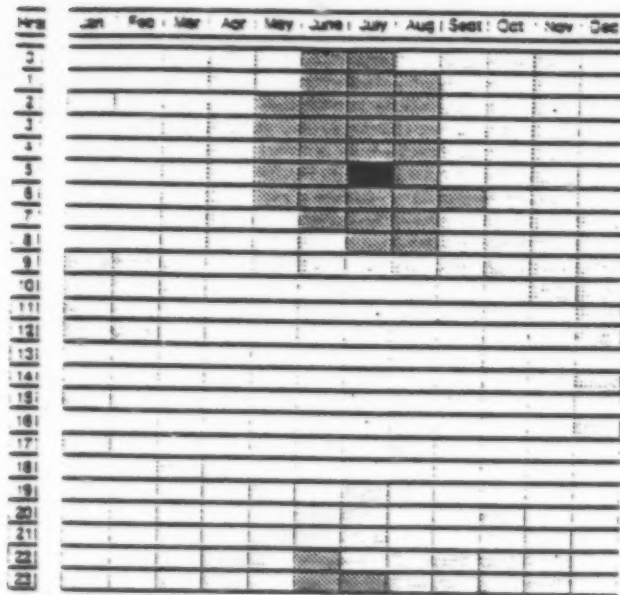
Yarmouth

Percent Frequency of Ceiling > 60m and Visibility > 800m

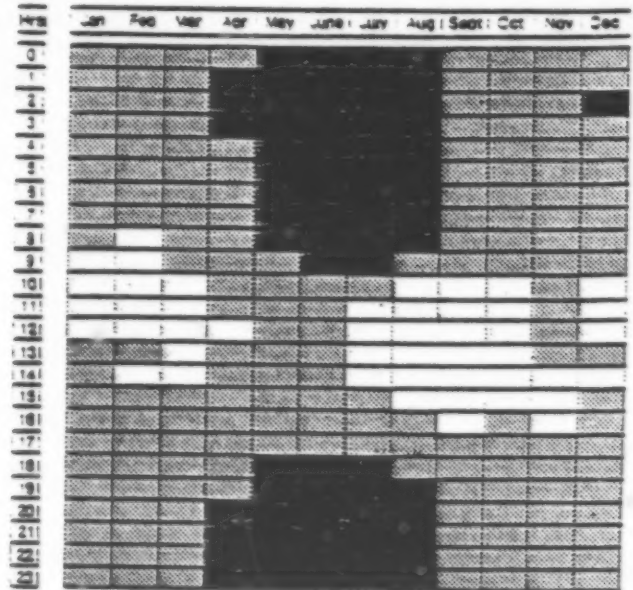


**SABLE ISLAND - IFR category 1
offshore airport alternative**

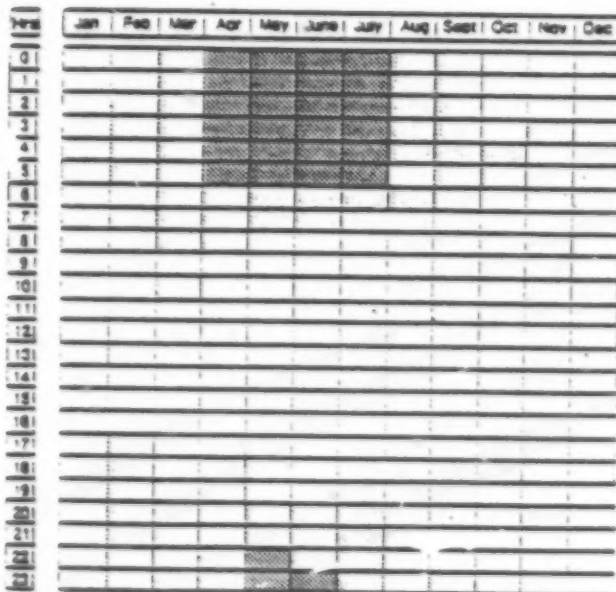
figure 3



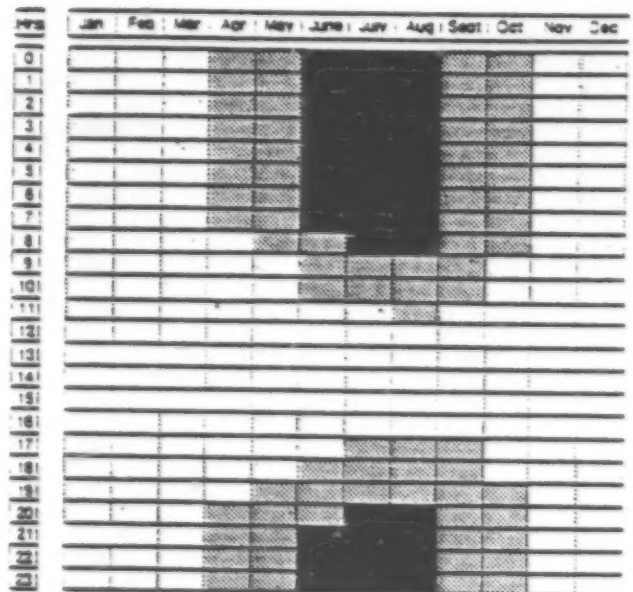
Halifax



Sable Island - offshore (simulated)

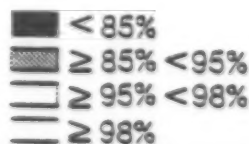


Sydney

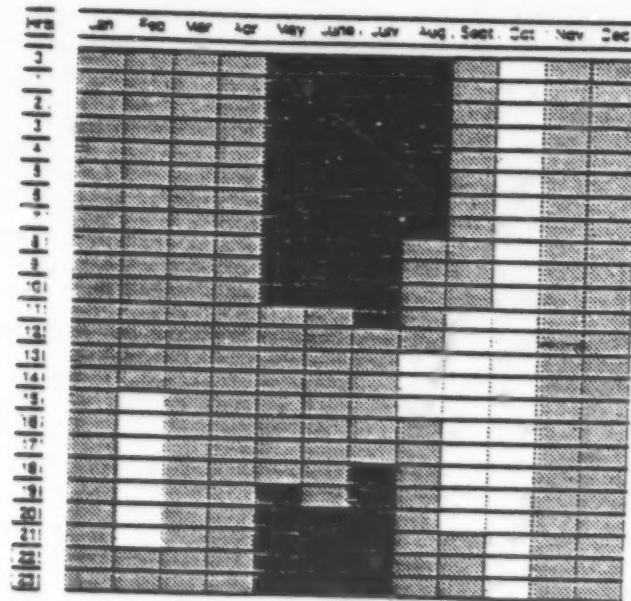


Yarmouth

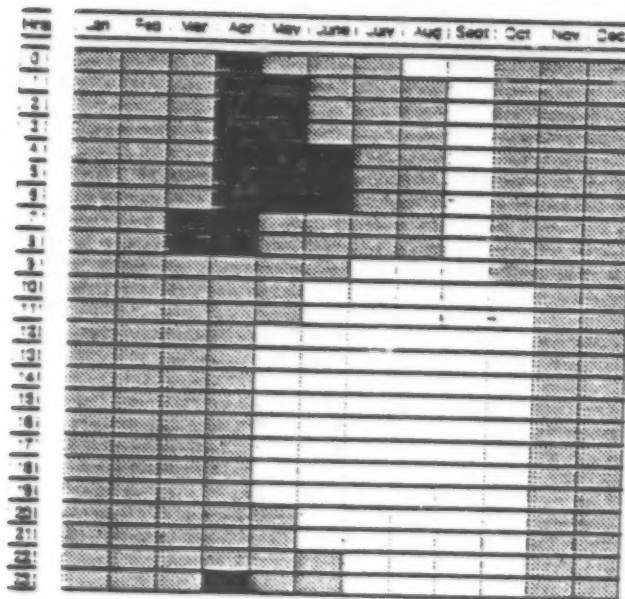
Percent Frequency of Ceiling > 30m and Visibility > 400m



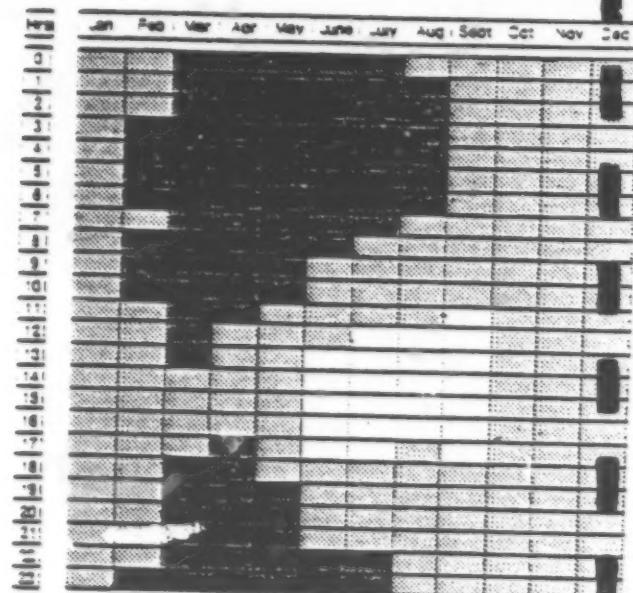
SABLE ISLAND - IFR category 2 offshore airport alternative



Hibernia (simulated)

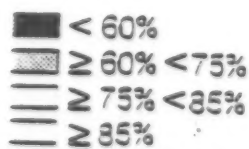


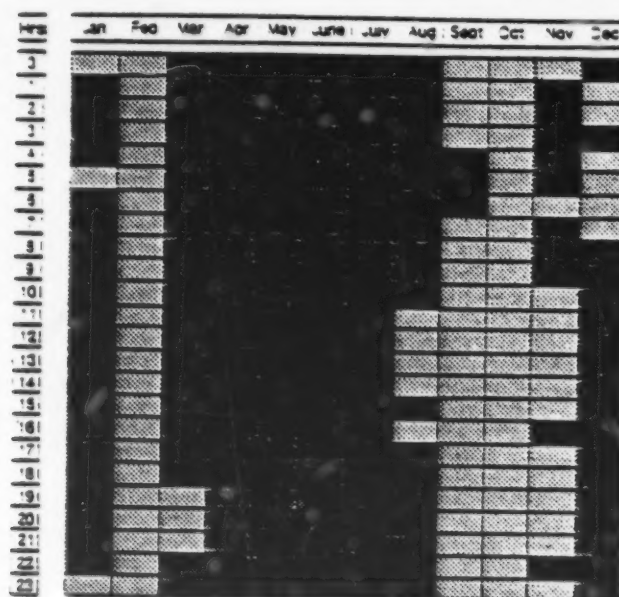
Gander



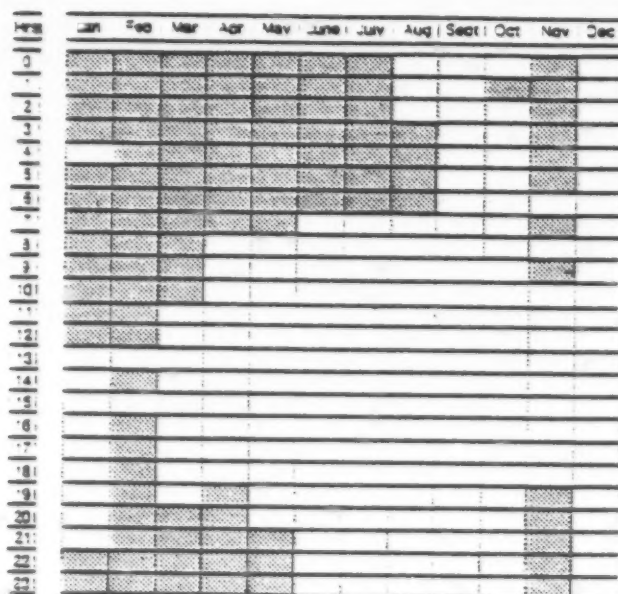
St. John's

Percent Frequency of Ceiling > 300m and Visibility > 4800m

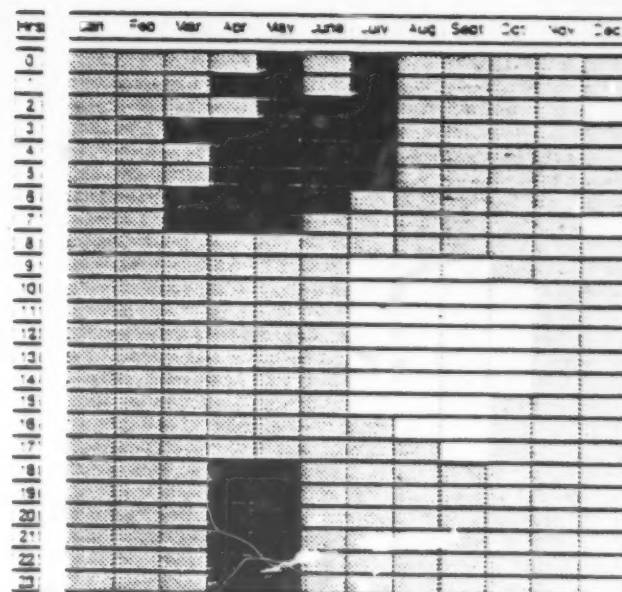




Hibernia (simulated)

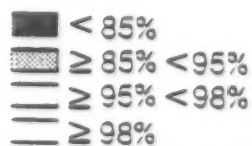


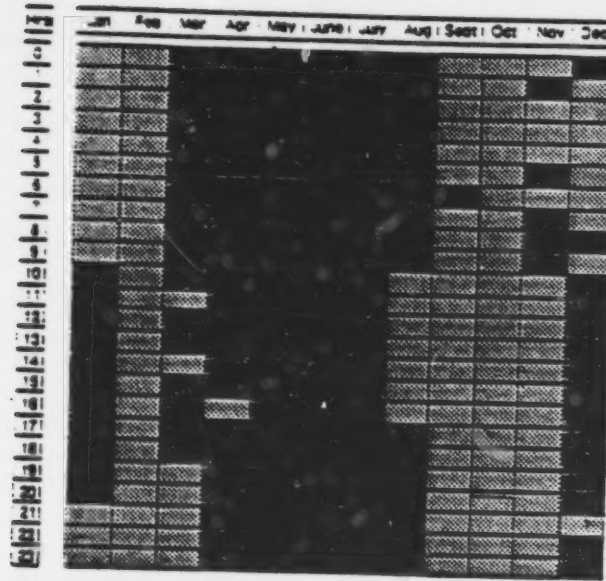
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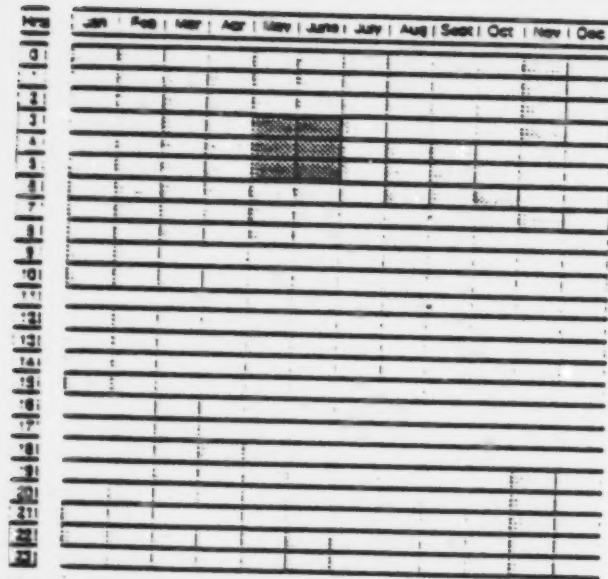
St. John's

Percent Frequency of Ceiling > 60m and Visibility > 800m

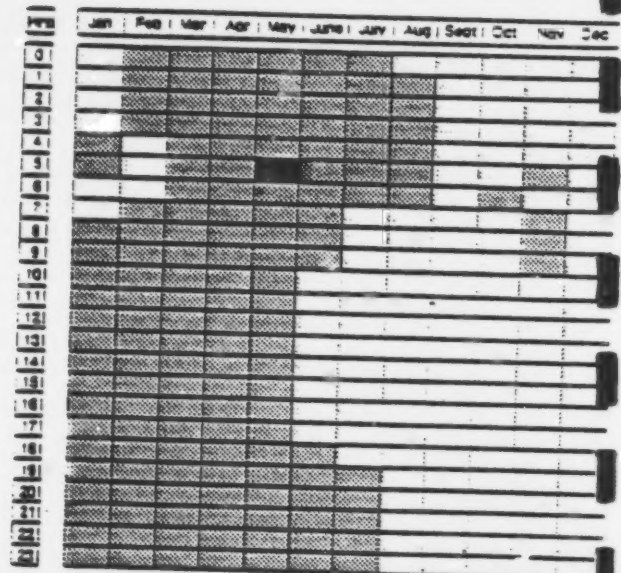




Hibernia (simulated)

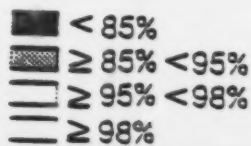


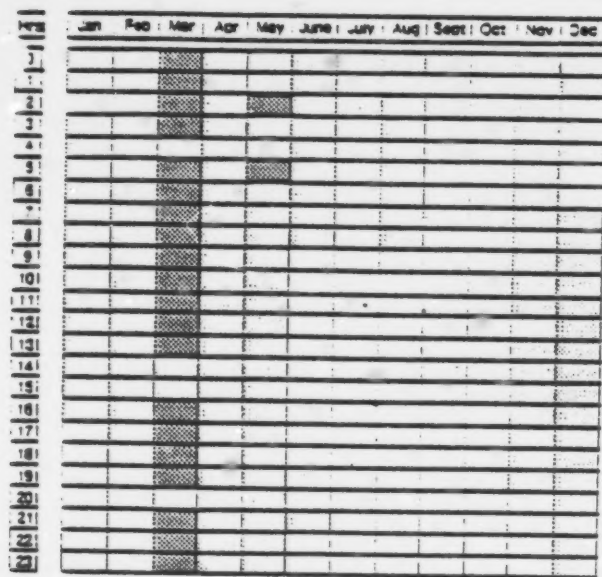
Gander



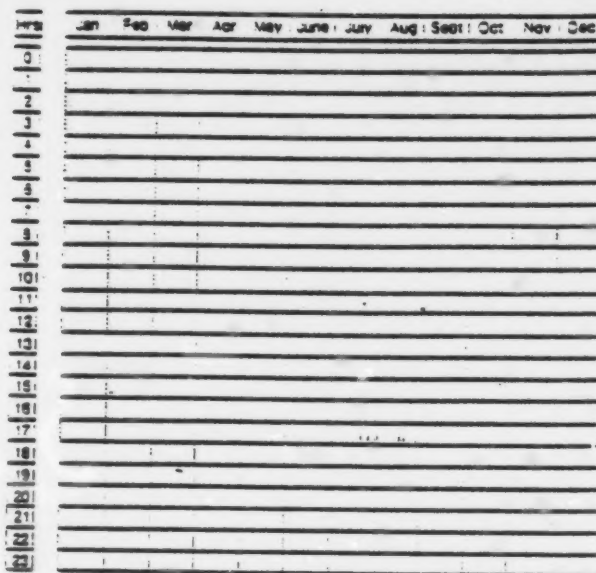
St John's

Percent Frequency of Ceiling > 30m and Visibility > 400m

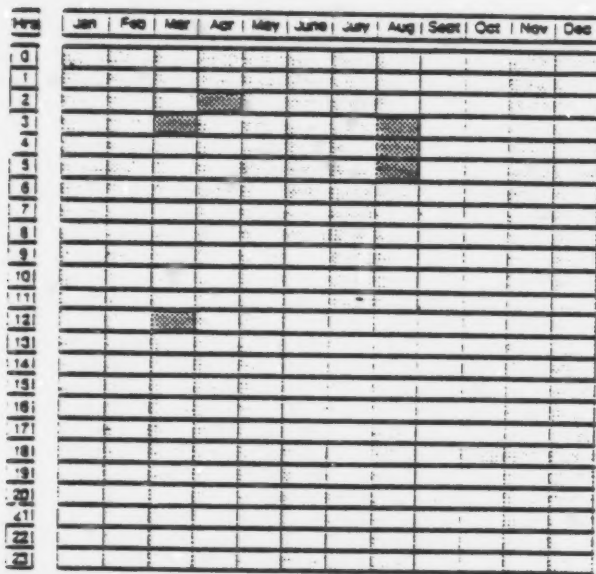




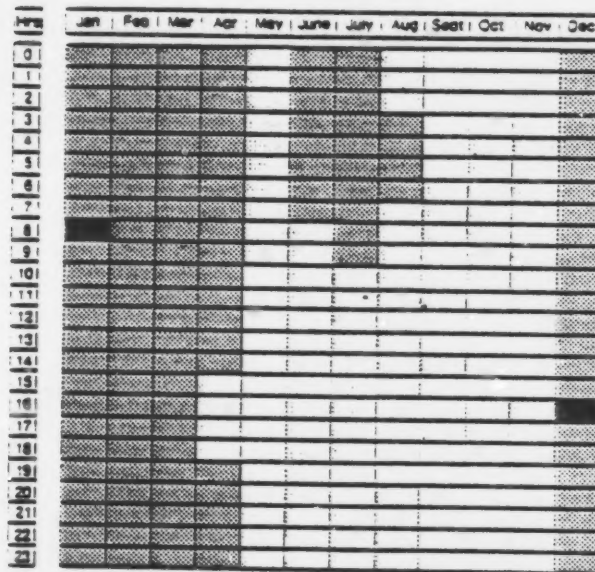
Cartwright



Goose Bay

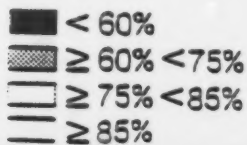


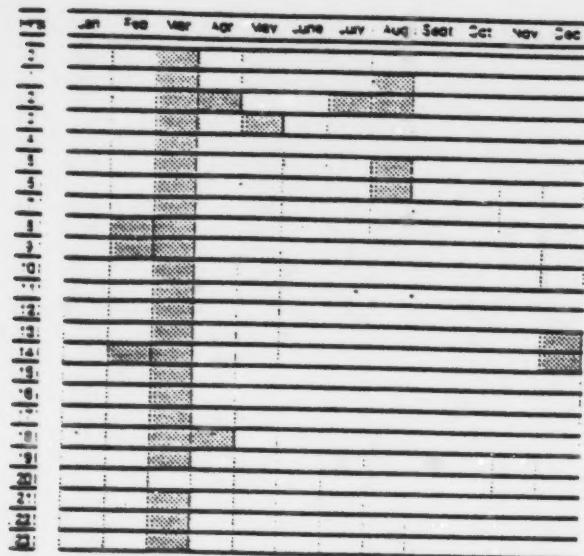
Hopedale



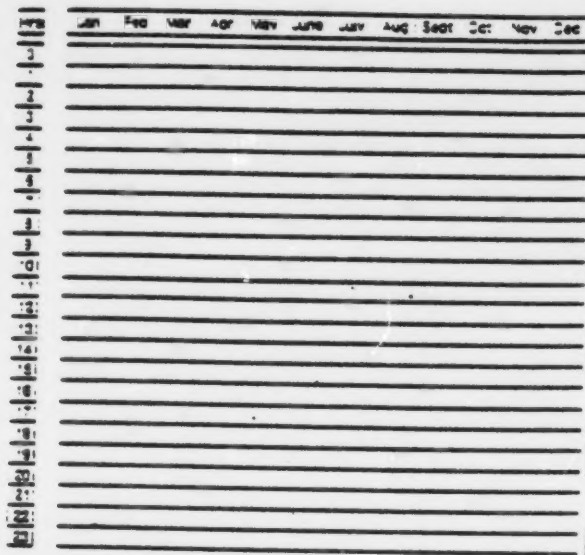
Labrador Sea (simulated)

Percent Frequency of Ceiling > 300m and Visibility > 4800m

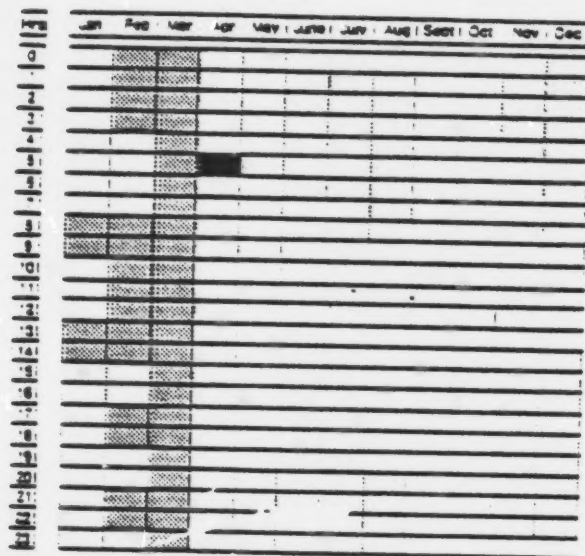




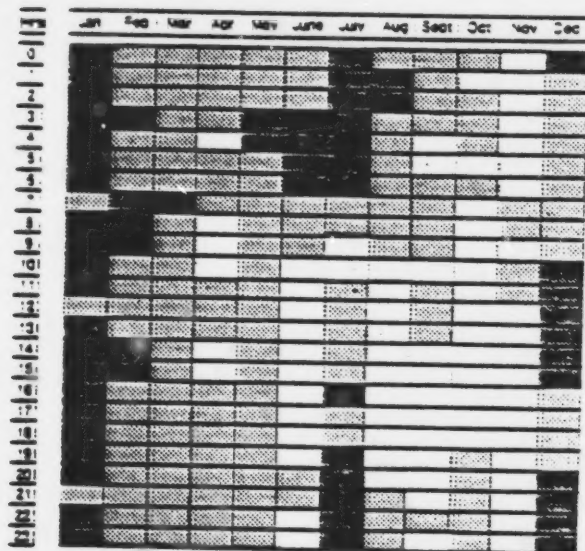
Cartwright



Goose Bay

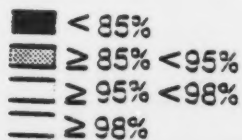


Hopedale



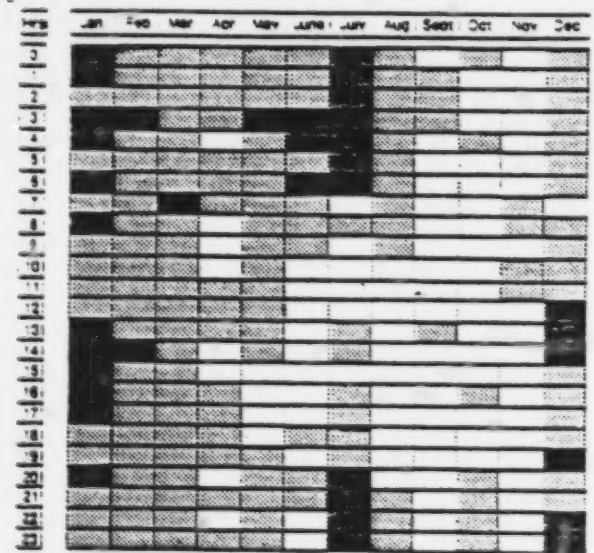
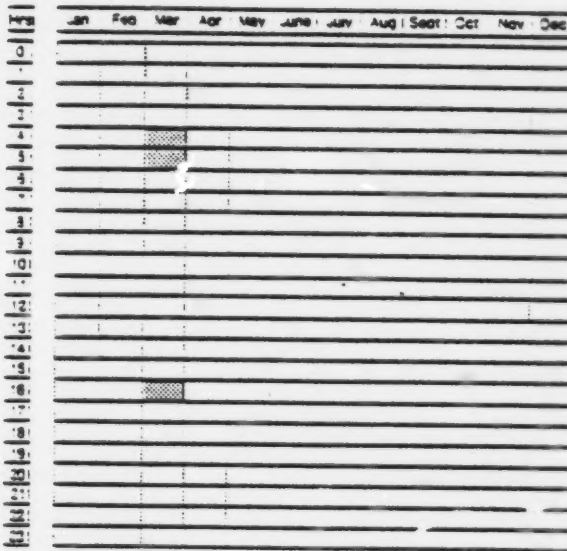
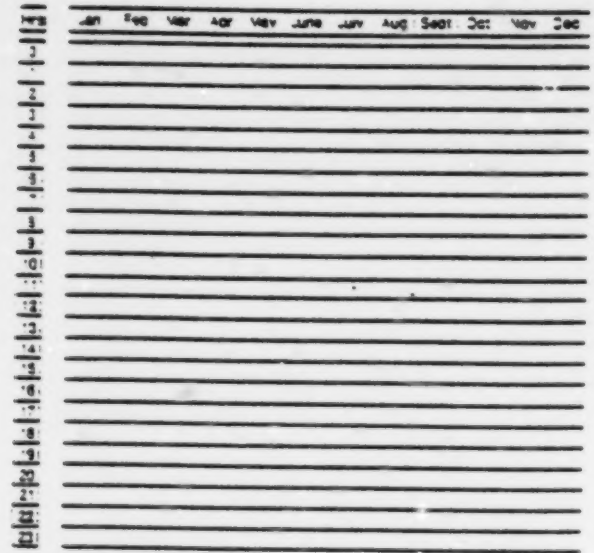
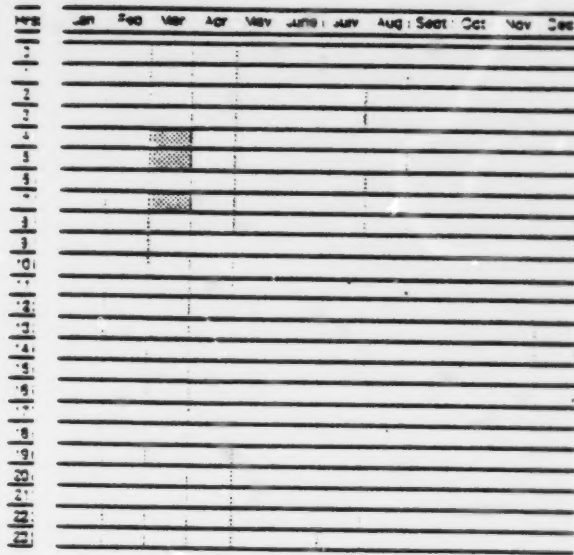
Labrador Sea (simulated)

Percent Frequency of Ceiling > 60m and Visibility > 800m

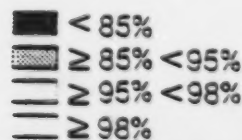


LABRADOR SEA
IFR category 1

figure 9

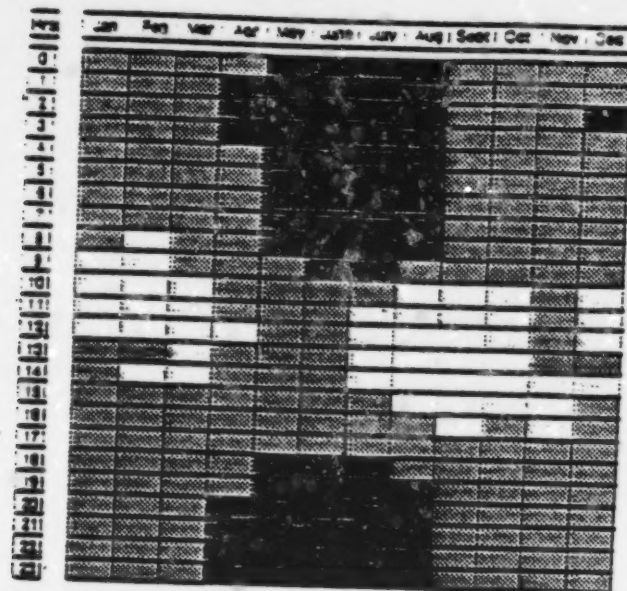


Percent Frequency of Ceiling > 30m and Visibility > 400m

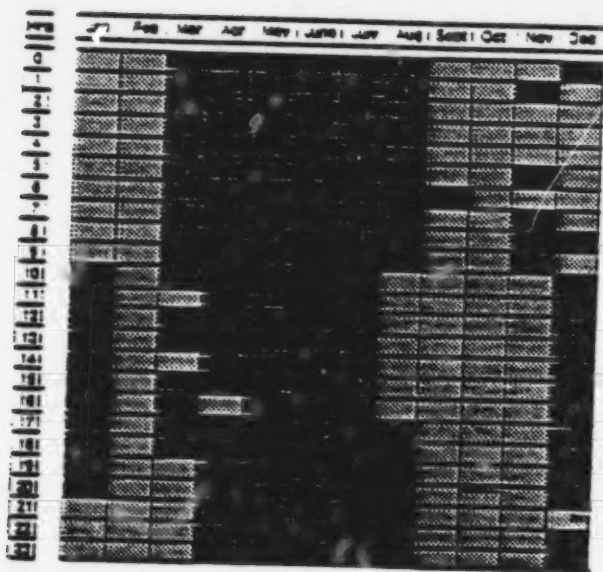


LABRADOR SEA
IFR category 2

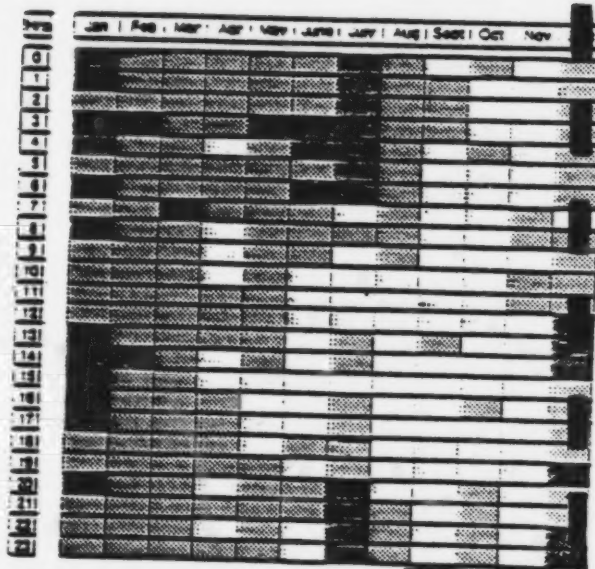
figure 10



Sable Island - offshore



Hibernia



Labrador Sea

Percent Frequency of Ceiling > 30m and/or Visibility > 400m

- < 85%
- ≥ 85% < 95%
- ≥ 95% < 98%
- ≥ 98%

IBI GROUP

VISIBILITY - IFR category 2

figure 11

At land-based airports, currently approved operating minima for helicopters operating to offshore sites is set at 60m ceiling and 800m visibility, based on the use of a front-course instrument landing system approach with glideslope and azimuth in operation.

At the rigs, the corresponding limits are 45m ceiling and 800m visibility using non-directional and transponder beacons as well as airborne radar. Visual contact with the water must be made 3.2km in advance of approaching the rig for final descent.

Optimal conditions for flying (VFR) to the Scotian Shelf are most likely in the month of September, while at Newfoundland Shelf on average they seldom occur over extended periods. At Labrador Sea, under daylight conditions they extend from May to November³. The least desirable visibility conditions exist during July at the Scotian Shelf; the entire months of May, June, July at Newfoundland Shelf, and sporadically in December and January at the Labrador Sea location.

Referring to the figures presented, time slots of probable favourable flying weather or "time windows" for offshore and mainland airports can be compared for determining flight scheduling problems. If a number of trips are required during periods of limited visibility (or narrow time windows) it may be necessary to schedule several aircraft over a narrow time slot rather than the more efficient option of having fewer aircraft making several trips during the day.

³ Climatic data supplied by Atmospheric Environment Services, Environment Canada.

For detailing on weather data simulation methodology refer to the Study Design Report, IBI Group.

The probability of acceptable conditions at IFR Category II levels for Halifax and Sydney is greater than that for Yarmouth. Yarmouth experiences similar visibility problems as does Sable Island. This could be a key consideration in selecting supply bases to serve the western areas of the Scotian Shelf.

For the Newfoundland Shelf system, weather conditions below IFR Category II levels are not likely to be restrictive. From an aviation point of view Gander represents a better choice of main supply base for the Labrador Sea Area than does St. John's.

Visibility at land base airports within the Labrador Sea system is good and should not pose a major problem for trip scheduling.

Points inland from St. John's are believed to have superior weather conditions. This aspect could be further investigated to determine whether, in the longer term, a more suitable site for heliports/STOLport operation is available.

3.3.2 Winds

Prevailing winds at all three areas are westerly. Windspeeds of 15 knots or more occur at the Scotian Shelf for intervals totalling 172 days per year, while similar windspeeds occur at the Newfoundland Shelf and Labrador Sea areas for intervals totalling 157 days and 172 days respectively. High windspeeds hinder aircraft movements, especially when windshear, cross winds or freezing spray conditions are involved. Strong winds also contribute to extreme sea states which influence the oscillation of the floating platform, varying the relative angle of approach and the touchdown point for landing aircraft.

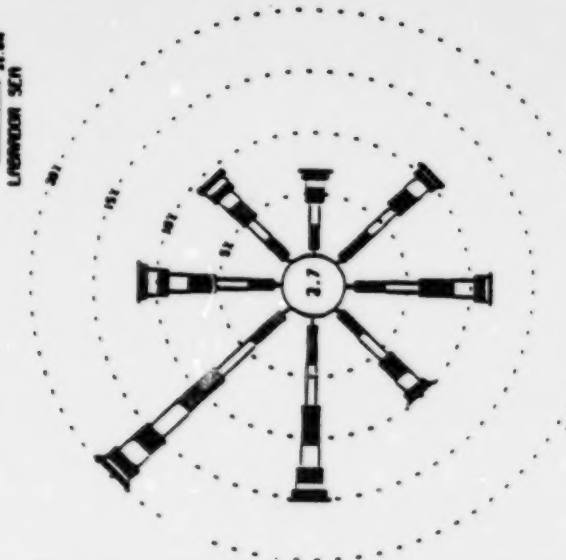
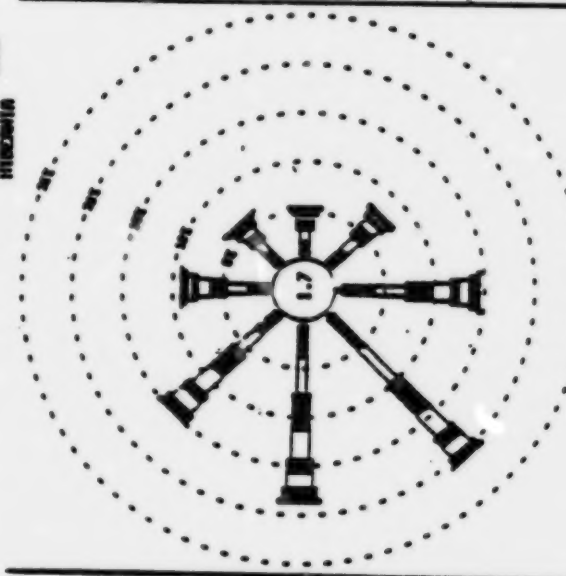
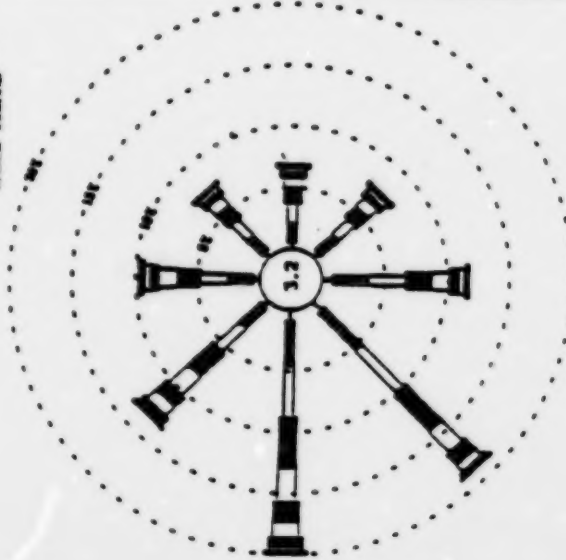
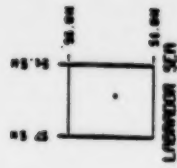
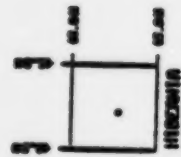
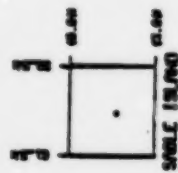
The influence of wind on aircraft operations is described in detail in part 8.1 Aircraft Certification Characteristics.

AREA	DIRECTION	WINDSPEED (KNOTS)	% OF TOTAL TIME
Scotian Shelf/ Sable	-	Calm (0-2)	3
	West	15 or more	38
	All	15 or more	47
	All	20 or more	28
	All	30 or more	16
Newfoundland Shelf/Hibernia	-	Calm (0-2)	2
	West	15 or more	32
	All	15 or more	43
	All	20 or more	32
	All	30 or more	3
Labrador Sea	-	Calm (0-2)	3
	West	15 or more	24
	All	15 or more	47
	All	20 or more	26
	All	30 or more	28

Wind Characteristics

Table 5

Since helicopters and the Dash-7 have relatively low cruising speeds, their effective ground speeds and fuel consumption will be significantly influenced by the frequency, direction and strength of the wind components paralleling the routes to be flown. A consideration of the magnitude of this effect for the three locations examined is shown in Table 6.



Frequency of Wind Speed by Direction for
 Offshore Exploration Areas

AREA	DESCRIPTION	% TIME PER ANNUM
Scotian Shelf	SE headwind affecting onshore to offshore trips	3
	NW tailwind affecting onshore to offshore trips	10
New- found- land Shelf	E headwind affecting onshore to offshore trips	3
	W tailwind affecting onshore to offshore trips	17
Labrador Sea	NE headwind affecting onshore to offshore trips	17
	SW tailwind affecting onshore to offshore trips	5

Headwind/Tailwind Occurrences* Effecting Aircraft
Fuel Consumption Calculations (< 20 knots)

Table 6

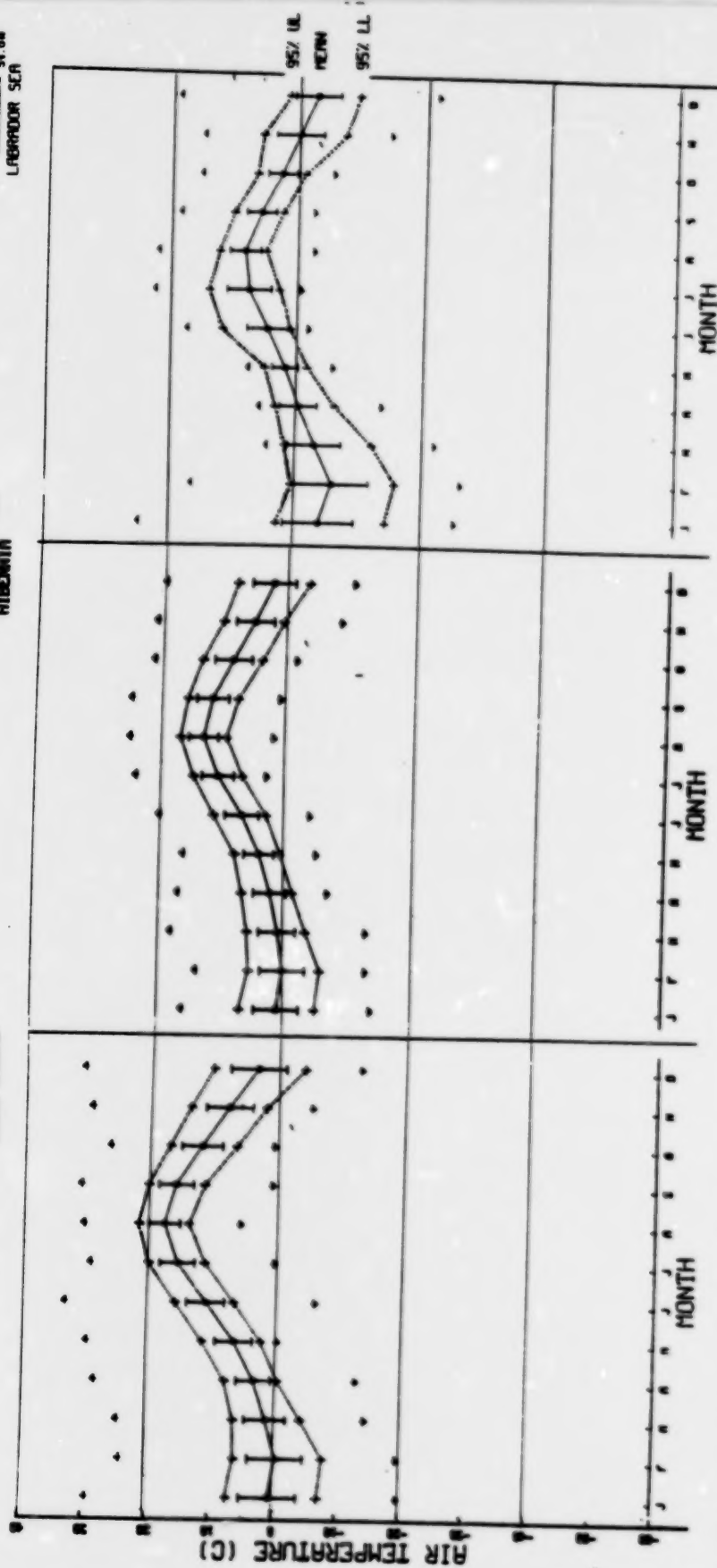
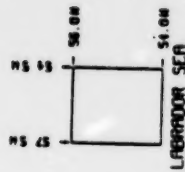
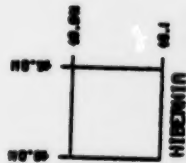
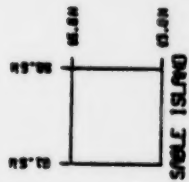
* Includes contributing winds originating within adjacent quadrants.

Information in Table 6 may be used in reverse to measure wind effects affecting offshore to onshore trips.

3.3.3 Air Temperatures

A major consequence of low temperatures or temperatures hovering around the freezing level coupled with the presence of suspended water droplets is aircraft icing. This condition, especially critical to helicopters can lead to:

- o aircraft engine failure;
- o excessive vibration or drag;
- o a decrease in visibility;
- o the formation of slippery manoeuvring surfaces.



Air Temperature for

Offshore Exploration Areas

Average mean temperatures of less than 5°C occur during the winter and spring months of December to April at the Scotian Shelf and Hibernia Area, while at the Labrador Sea they occur from October to May. The coolest temperatures have ranged from -20°C at the Scotian Shelf, -12°C at the Hibernia area to 28°C at Labrador Sea.

3.3.4 Freezing Spray

Freezing spray conditions, which are a function of sea state, winds, and temperature occur in all three offshore locations from late autumn to mid spring. The Labrador Sea area is the most severely affected, as depicted on Figure 14. The invasion of airborne salt spray is detrimental to aircraft operations aboard the STOLport because it results in:

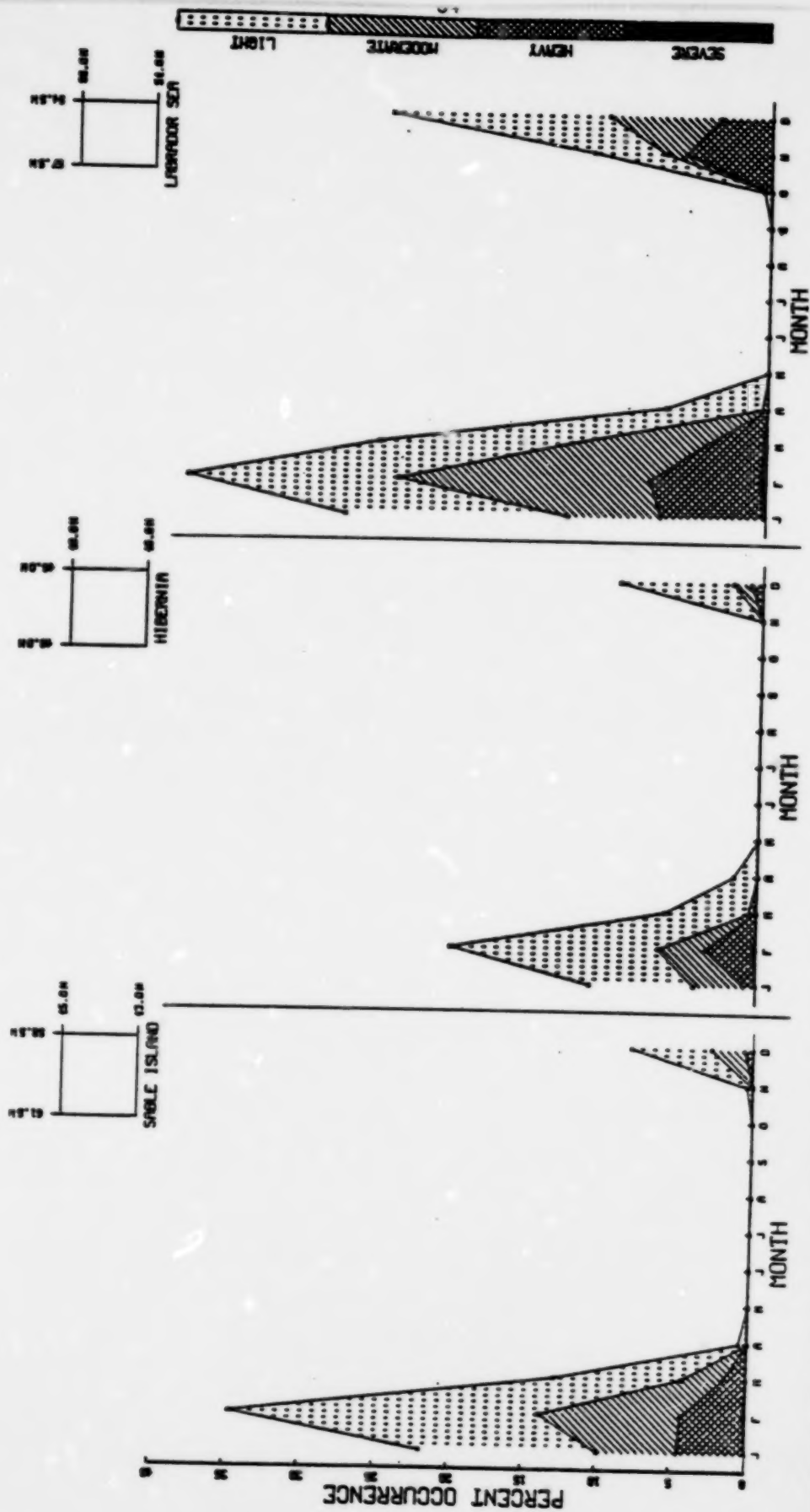
- o icing of aircraft and manoeuvring surfaces;
- o corrosion;
- o reduced visibility.

Light to severe conditions for each offshore site are presented in Table 7.

LOCATION	SPRAY CONDITION (AES CATEGORIES)	INTERVALS TOTAL- LING (HRS/DAY)	SEASON
Scotian Shelf	Light	up to 8	Oct - May
	Medium	up to 3	Nov - April
	Heavy	up to 1	Nov - April
	Severe	up to 0.1	Jan - Mar
Newfoundland Shelf	Light	up to 5	Nov - May
	Medium	up to 2	Nov - April
	Heavy	up to 1	Nov - Mar
	Severe	up to 0.1	Jan - Mar
Labrador Sea	Light	up to 10	Sept- May
	Medium	up to 6	Oct - May
	Heavy	up to 2	Oct - April
	Severe	up to 0.2	Jan - April

Freezing Spray Conditions

Table 7



Freezing Spray Potential for
 Offshore Exploration Areas

3.4 Marine Weather

3.4.1 Visibility

Reduced visibility does not affect the STOLport vessel or artificial island facilities directly, but could be problematic for the navigation of marine vessels, the construction phase of artificial islands, or the relocation of the STOLport or heliport vessels.

3.4.2 Winds

High winds produce sea states which can affect the structural integrity and safety of passenger vessels, the artificial island, the floating STOLport and heliport concepts considered in this study. These conditions also hamper the landing of aircraft on the floating heliport or STOLport, the docking of vessels alongside the floating STOLport or heliport or artificial island and the transfer of personnel and cargo between oscillating platforms or decks.

The influence of wave action on both the artificial island and floating airport concepts is discussed in detail in Section 9.0 Offshore Base Concepts.

3.4.3 Air Temperatures

Icing is a hazardous condition that is likely to occur in this marine environment, resulting in slippery manoeuvring surfaces and the coating of platform hardware. This type of condition can be caused by the freezing of precipitation or airborne sea spray. Both pose a problem because of sudden accumulation. The effect of air temperatures on the availability of facilities or on operating economics was not addressed separately in this study but was allowed for indirectly in the estimates of manpower and operating costs.

3.4.4 Freezing Spray

Freezing spray is detrimental to vessels because of the resultant accumulation of ice, and the effects of corrosion on vessel surfaces. Freezing spray should pose less of a problem to an artificial island due to its larger size and configuration. The weather data indicates that keeping aircraft landing and takeoff surfaces free of ice is an important safety and operating cost consideration. The operating manpower estimates for the various concepts studied, take into account the requirement to keep critical surfaces free of ice during aircraft operating periods.

3.4.5 Sea State

The effects of wave action on a floating STOLport, artificial island or passenger vessel are of major importance from a vessel safety point of view, because of the stresses placed on the various structures and moorings, and because of the limitations placed on aircraft operations. Transfer of passengers and cargo between modes of transport particularly between the floating airport concept and marine vessels is sensitive to the differential vertical and horizontal displacements resulting from active seastates. An important consideration addressed in the study was the determination the critical sea state for various operations and the percentage of time such critical states would be exceeded.

An important consideration was the critical sea state for fixed wing aircraft landing operations. For an aircraft landing on a floating STOLport, the pilot must not only compensate for the heaving of the vessel to control his touchdown point, but must also consider the resulting vertical closing velocity which must not exceed the safety limits of the aircraft undercarriage. If passengers are being transferred between a passenger vessel and a floating or fixed STOLport,

levels of horizontal and vertical displacement between the modes have to be addressed. Further discussion of these limiting factors are presented under section 8.0. Fixed Wing Aircraft and 9.0 Alternate Concepts.

Extreme wave data for the 1:50 and 1:100 year conditions for the three study areas was not available, so estimates for these periods were calculated on the basis of the available 1:10 year data. Table 6 shows actual and predicted wave size probabilities.

On the basis of the available information, the heliport and STOLport "design" wave (or most extreme condition, for the various design criteria, to be encountered at the off-shore location), has the following characteristics⁴:

- o maximum significant wave height of 18 metres;
- o extreme wave height of 36 metres;
- o wave length of 600 metres;
- o wave duration, 20 seconds.

⁴ Neu, N.J.A., 11-Year Deep Water Wave Climate of Canadian Atlantic Waters, Canadian Technical Report of Hydrography and Ocean Sciences No. 13. October, 1982.

LOCATION	ACTUAL				PREDICTED			
	ANNUAL		1:10 YEAR		1:50 YEAR		1:100 YEAR	
	SIGNIFI- CANT	MAX.	SIGNIFI- CANT	MAX	SIGNIFI- CANT	MAX	SIGNIFI CANT	MAX
SABLE	8.7	15.7	11.7	21.0	14.2	25.6	15.3	27.6
SCOTIAN SHELF	8.5	15.3	11.6	20.9	14.1	25.4	15.2	27.4
HIBERNIA	9.0	16.2	12.3	22.2	14.6	26.3	15.6	27.4
NEWFOUND- LAND SHELF	9.1	17.1	12.7	22.8	15.1	27.2	16.1	29.0
LABRADOR SEA	9.3	16.8	12.5	22.5	14.9	26.8	16.0	18.9

Sea State

Table 8

3.4.6. Sea Ice

The occurrence of sea ice at the Newfoundland and Scotian Shelf locations is infrequent⁵ The Labrador Sea area is covered with up to 9/10ths concentration during the winter and spring months, annually.

Sea ice does drift into the northern fringes of both the Newfoundland and Scotian Shelves during the majority of years. The average southern ice limit during the period from late February until mid-March is near latitude 45°30'N over the Scotian Shelf and near latitude 48°N over the Newfoundland Shelf.

With regard to the Labrador Sea area, sea ice extends, on the average, from the coastline to approximately 150 to 200 nautical miles offshore

⁵ Markham, W.E., Ice Atlas-Eastern Canadian Seaboard Atmospheric Environmental Services Publication E-56-55/1981.

during the winter and spring months. Beyond this limit, the occurrence of sea ice is infrequent and depends primarily upon windflow patterns and the severity of winter temperatures.

Ice thickness is more than 30cm along the Labrador coast. The average seasonal maximum ice thickness is 8 to 120cm while offshore it can be up to 150cm. Multi-year ice may also be embedded in the first year ice.

FLOE SIZE (maximum dimension-metres)	PER CENT COVERAGE
30 - 50 m+	14
20 - 30 m	19
10 - 20 m	14
Over 10 m	53

Floe Size and Distribution Labrador Sea*⁶

Table 9

* Post Blenkarn and Knapp, 1969⁷

Researchers at Mobil Oil Canada Limited predict 2 to 3 ice floes with a thickness of 2-3 metres, with a compressive strength range of 1.6 to 10.3 mPa will occur off the coast of Newfoundland.

⁶ Lewis J.K. and Benedict C.P., Burial Parameters: An Integrated Approach to Limit Overdesign. Proceedings of the Symposium on Production and Transportation Systems for the Hibernia Discovery, St. John's, 1981.

⁷ Blenkarn, K.A., Knapp, A.E., Ice Conditions on the Grand Banks, CIM Special Volume 10 The Ice Seminar Knapp, A.E., 1969.

3.4.7 Icebergs

The total number of icebergs that drift from the west coast of Greenland along the "Iceberg corridor" south of Cape Chidley into the vicinity of the Newfoundland Shelf and Labrador Sea areas is estimated at 1200 annually. The Scotian Shelf is essentially iceberg-free. The international ice patrol estimates that on average 28 icebergs cross latitude 48°N annually (1946-1979 data) with the extremes ranging from zero in 1966 to 1584 in 1972.

Icebergs range in magnitude from "berg bits" and "growlers" under 1.5 metres in height, 5 metres in length and 0.001 million tonnes in weight, to "very large bergs" which are over 100 metres high, over 220 metres in length and over 10 million tonnes in weight. The size and percent distribution of icebergs present in the Labrador Sea and Newfoundland Shelf Area per degree latitude, are listed in Table 10.

POSSIBLE LOCATION	LAT. ° N	GROWLERS*	SMALL*	MEDIUM*	LARGE*
Labrador Sea Area	60	6.4	43.3	33.5	16.8
	59	4.2	49.9	29.4	15.5
	58	4.2	48.0	36.6	11.2
	57	4.3	41.9	42.2	11.7
	56	5.1	51.6	34.1	9.3
	55	3.9	61.4	27.8	7.0
Newfoundland Shelf Area	54	16.6	52.3	24.5	6.7
	53	10.2	52.4	26.5	10.9
	52	16.7	52.2	24.6	6.5

Iceberg Distribution (% at each latitude)⁸

Table 10

* International Ice Patrol Iceberg Size Classification.

⁸ McIntyre N.F., Mobil Oil Canada Ltd., Environmental Forces on a Fixed Platform and the Ability of the Platform to Resist Them. Proceedings of the Symposium on Production and Transportation Systems for the Hibernia Discovery. St. John's Newfoundland. February 16-18, 1981.

The review of sea ice and iceberg conditions indicates that the operation of a floating airport would be seasonal at the Labrador Sea and subject to occasional disconnection at the Newfoundland Shelf, under threat of collision with an iceberg or extreme pack ice pressure.

3.5 Human Environment

Low air temperatures, combined with precipitation, strong winds and freezing spray causes a decrease in the performance of deckhands through the discomfort experienced as chill, or from the threat of injury due to slippery surfaces. In extreme situations, personnel may be severely hindered or incapacitated through hypothermia, stress, or accidents.

Levels of discomfort due to windchill are presented on Figure 15.

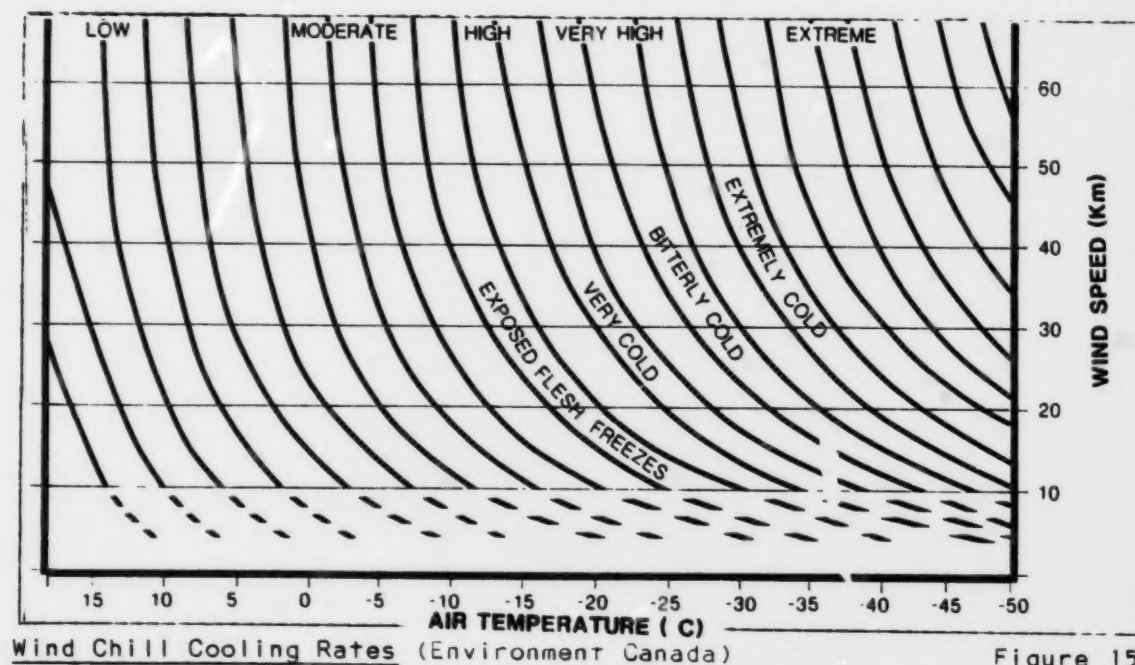


Figure 15

3.6 Navigational Aids

An obstruction-free environment, and adequate shelter must be provided for navigational aids to ensure effective operation under all climatic situations. The facilities should therefore, be relatively

- o stable during vessel movement
- o wind resistant
- o water resistant
- o humidity controlled
- o temperature controlled
- o dust free and
- o fire resistant.

to ensure the integrity of the equipment and the resultant safety of personnel.

4.0 DEMAND FORECAST

4.1 Phases of Development

Exploration, assessment and development activated at the three major east coast offshore areas are expected to follow similar patterns but within different time frames. Based on discussions with petroleum industry representatives, the following describes the most likely progression for offshore resource development, from pre-production or exploration phase to resource recovery phase, for each of the three study areas involved.

The demand forecasts are developed for two phases, these being:

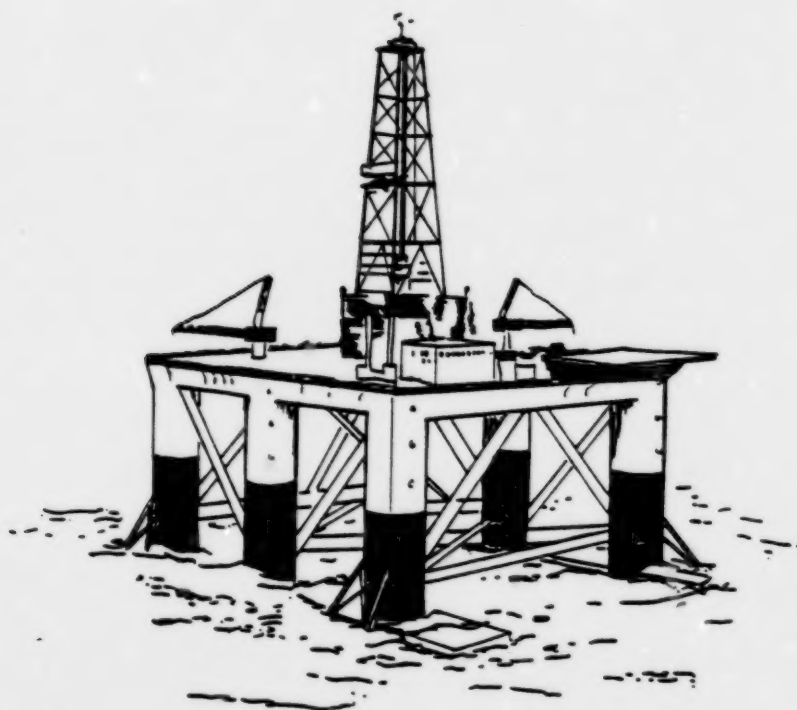
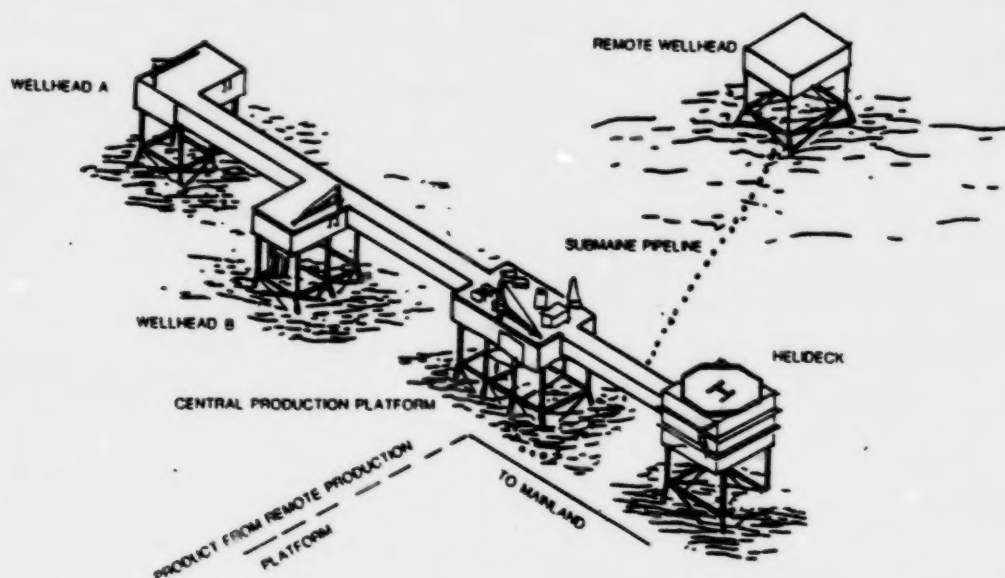
- a) The preproduction phase, including exploration, assessment, and placing of production platforms.
- b) The production stage, which will also involve exploration and assessment but at a lesser scale.

4.2 Preproduction Phase

The preproduction activities will take place over wider geographical areas than the 50 nm radius circular zones assumed, but production activities are expected to be more concentrated, and demands identified are believed to be representative of activities likely to take place within the 50 n.m. radius zones at least during the early stages of production.

Scotian Shelf

- o Construction and development is expected to begin in 1984, with year round activities.
- o Up to four exploration units could be in operation in this area at any one time.
- o Beyond 1987 one exploration unit will be in the area.



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TYPICAL OFFSHORE PRODUCTION COMPLEXES

figure 16

- o 70-90 men based on each unit, for each of two 12 hour shifts, two week rotation.
- o The numbers of exploration units and associated personnel requirements are:

YEAR	NUMBER OF UNITS	PERSONNEL BASED ON UNITS	AVERAGE DAILY TRANSFER OF PERSONNEL*
1983-85	3-5	210-450	21-45
1986	2-4	140-360	14-36
1987	1-2	70-180	7-18
1988	1	70	7

* One way, assuming flights on 5 weekdays each week.

Newfoundland Shelf

- o As this area is extremely large, only about one third of the number of drilling units (2-4) projected will be active within the delineated area at any one time. Construction and development is expected to commence around 1987 with significant production commencing by about 1991.
- o Beyond 1990, the number of exploration units is to decline as exploration relocates to other zones.
- o The numbers of exploration units and personnel involved are:

YEAR	NUMBER OF UNITS	PERSONNEL ON UNITS	AVERAGE DAILY TRANSFER OF PERSONNEL
1983	2-4	140-360	14-36
1984-86	3-5	210-450	21-45
1987-90	2-4	140-360	14-36
1991	1-3	70-270	7-27
1992	1-2	70-180	7-18
1993	1	90	9

Labrador Sea

- o Only one exploration unit is likely to be active within the delineated area at any one time, generating a requirement for 70-90 people, an average of 7-9 people being transferred on a daily basis.
- o Construction and development is expected to begin in the early to mid 1990's, with production commencing at modest levels in the late 1990's.

4.3 Production Phase

4.3.1 Development Strategy

Two alternative development strategies are under consideration.

1. A centralized strategy involving large production platforms capable of directly tapping an area of approximately 6.4 square kilometres and connected, by undersea pipeline, to three or four satellite wells.
2. A decentralized strategy consisting of groups of up to four smaller platforms each capable of producing from an area of approximately one square kilometre.

The present intention is to employ the decentralized strategy on the Scotian Shelf. The strategy to be employed in the Hibernia system is still undecided and is even less certain for the Labrador Sea area.

The range of personnel requirements for the various facilities associated with each strategy is shown on Table 11.

The assumed breakdown of personnel requirements for specific functions for three assumed production levels; minimum, most likely and maximum are shown in summary form in the following table:

CENTRALIZED STRATEGY

- o Involves one large production platform capable of producing from an area up to six square kilometres around it.
- o Up to four development rigs used to drill satellite wells to be linked to the main platform by undersea pipelines of up to 25 kilometres in length; most likely estimate is one or two development rigs.
- o One workover rig.
- o One or two storage vessels to collect oil from each platform; most likely estimate is two vessels.
- o Personnel on each rig, platform or vessel:
 - main production platform - 100-140;
 - workover rig - 35-50;
 - development rig - 79-90;
 - storage vessel - 40-60.
- o Total personnel requirement (including those employed on the one exploration unit expected to be in operation in each zone):
 - minimum (no development rigs) - 350;
 - most likely (one or two development rigs) - 700;
 - maximum (three development rigs) - 1350.

DECENTRALIZED STRATEGY

- o Involves groups of up to four smaller production platforms, each capable of producing from an area up to one square kilometre around it; this strategy would involve a minimum of two, and most likely three groups of production platforms.
- o One or two storage vessels to collect oil from each platform; most likely estimate is two vessels.
- o Probably no satellite wells and therefore no development rigs once production platforms are in place.
- o One workover rig.
- o Personnel on each rig, platform or vessel as for centralized strategy.
- o Total personnel requirement (including those employed on the one exploration unit expected to be in operation in each zone):
 - minimum (two production platforms) - 400;
 - most likely (three production platforms) - 850;
 - maximum (four production platforms) - 1600.

OFFSHORE EQUIPMENT	MINIMUM		MOST LIKELY		MAXIMUM	
	UNITS	MANPOWER	UNITS	MANPOWER	UNITS	MANPOWER
<u>Centralized</u>						
Production platforms	1	150	2	300	3	450
Development rigs	1	100	3	300	7	700
Exploration rigs	1	50	1	50	2	100
Workover rigs	1	50	1	50	2	100
Storage vessels	-	-	-	-	-	-
TOTAL	4	350	7	700	14	1350
<u>Decentralized</u>						
Production platforms	3	350	6	750	12	1500
Development rigs	-	-	-	-	-	-
Exploration rigs	-	-	-	-	-	-
Workover rigs	-	-	-	-	-	-
Storage vessels	1	50	2	100	2	100
TOTAL	4	400	8	850	14	1600

Activity Levels-Centralized & Decentralized Strategy

Table 12

While the centralized strategy requires slightly fewer personnel, the apparent variations are not believed significant in the context of this study, and for the sake of simplicity the traffic levels corresponding to the decentralized strategy were used in the study.

4.4 Traffic Assumptions

The primary focus of the study was on the transportation requirements of the production phase. The annual number of trips generated by the based employees is a function of both the number of employees and their rotation period. The trip limits corresponding to the minimum, most likely and upper production levels are:

CASE	BASED EMPLOY- MENT	ANNUAL PERSON TRIPS		
		1 WEEK ROTATION	2 WEEK ROTATION	3 WEEK ROTATION
Minimum	400	41,600	20,800	13,900
Most Likely	850	88,400	44,200	29,500
Maximum	1,600	166,400	83,200	55,400

Relationship Between Person Trips and Based Employment

Table 13

In order to cover the forecast range and to ensure that the breakeven trip levels for all concepts can be determined, evaluations were carried out at 25,000 annual trips, increments from 25,000 to 100,000 annual person trips, and at 50,000 trips, increments thereafter to 300,000 annual person trips.

4.5 Impact of Delays

Delays in exchanging workers on the rigs, caused by unfavorable weather conditions, results in increased labour costs for:

- o overtime charges for the workers delayed on the rigs;
- o accommodation, food and standby costs for landside workers awaiting transport to the rigs.

For the overtime charges on the rigs the following cost factors are currently applicable for both exploration and production rigs:

- o 30 specialist workers at \$400 per day;
- o the remainder at \$100 per day;
- o for workers held on the land side awaiting transport to the rigs, \$100 per day for accommodation and food;
- o overtime on the rigs starts at noon on the day that the workers are scheduled to be removed.

The total incremental cost of any delay would be a function of the party size scheduled for transfer, which, in turn, is a function of the number of personnel based on the platforms; the size of the helicopters; the capacity/range characteristics of the helicopter employed and the trip frequency. Assuming party size of 14, the approximate direct cost of a missed service would be of the order of \$5,000-6,000 for (excluding helicopter standby costs).

5.0 LOGISTICS

5.1 Scope

On the Canadian east coast passengers are generally transported by direct flights, from shore based airports, by helicopters, to helidecks located on exploration platforms or supply vessels. This present service, which is referred to in this study as the Base Case, is likely to prevail for economic reasons throughout the perfected early exploration stages, since more sophisticated solutions are unlikely to be justified for the low traffic volumes currently envisioned. Operations are permitted during daylight hours only, and are delayed or cancelled during periods of marginal or unfavorable flying weather for reasons of safety. Fixed wing aircraft are not utilized due to the unavailability of suitable offshore landing facilities.

Present regulations prohibit the use of offshore helidecks based on rigs as IFR alternates. This then can pose a payload and range penalty for helicopters when there is a requirement to reduce all up weight to allow reaching the more remote alternate land-based airport.

The problems currently being experienced with offshore aviation systems will continue to increase both in terms of complexity and economic dis-benefits as the anticipated build-up of petroleum production related offshore employment materializes.

In the context of the objectives of this research study a number of alternative systems concepts were defined for the purposes of determining the practicability of improving the current system in the following areas:

- a) Reducing the costs and delays associated with rotary wing aircraft by the
 - o introduction of highly stable fully instrumented offshore heli-ports, capable of serving as IFR alternates, thereby reducing current effective stage lengths;

- o introduction of improved landing systems at special purpose heliports to reduce adverse weather related delays;
 - o grouping of flights to a centralized offshore heliport for distribution to the platforms, thereby improving load factors on the long haul stages.
- b) Reducing aviation systems costs through the substitution of fixed wing STOL aircraft for rotary wing aircraft giving rise to the following potential benefits:
 - o reduced flying time for passengers;
 - o improved service quality, reliability and convenience;
 - o greater flexibility in the number and location of onshore supply bases and related employment centres;
 - o increased scope for improved service reliability during adverse weather conditions;
 - o economic benefits to the Canadian aircraft manufacturing community.
- c) The possible supplementing of offshore based heliports and STOLports with advanced marine personnel transport vessels to overcome delays associated with helicopter operations at offshore platforms.
- d) Increasing the efficiency and reliability of both fixed wing and rotary wing aircraft aviation systems through improved navigation, communications and electronic landing systems.

5.2 System Variables

In order to assess the technical feasibility and practicality of improving the existing service, it was necessary to examine each major component of the Base Case service, in the context of the variables listed below. This evaluation takes into account forecasts of demand and the likely timing of related technological advancements. Relevant technological improvements which could not likely be contained within the time frame of the study were not examined. Trip network analysis variables were:

- o geographical location of the offshore production areas
- o number and location of onshore supply bases
- o distance by air between onshore bases and offshore locations
- o number of platforms to be served by a single flight
- o based staff per platform
- o staff rotation period
- o flight frequencies
- o aircraft capacity, range and operating cost.

5.3 Transportation System Alternatives

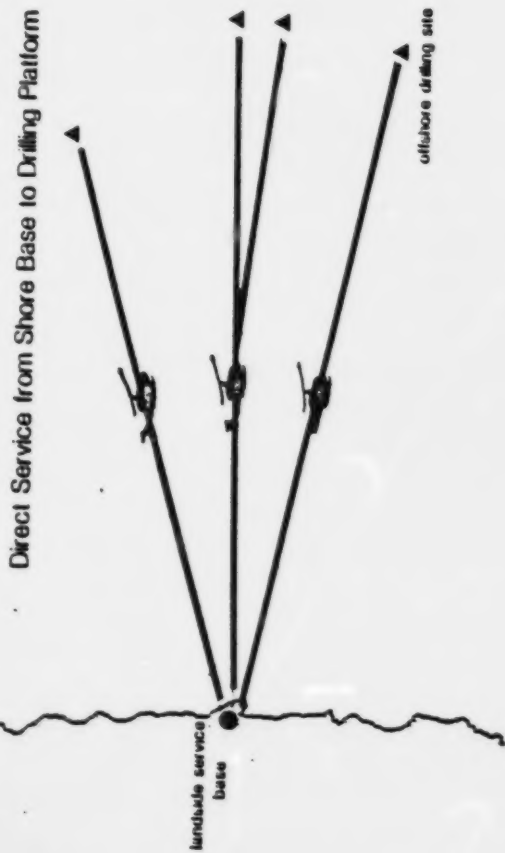
Three alternative systems concepts were developed for evaluation and comparison with current or base case operations. These options are described below and along with the Base Case scenario (Direct service from shore base to drilling platform) are depicted on Figure 17.

Central Service Base on Artificial Island

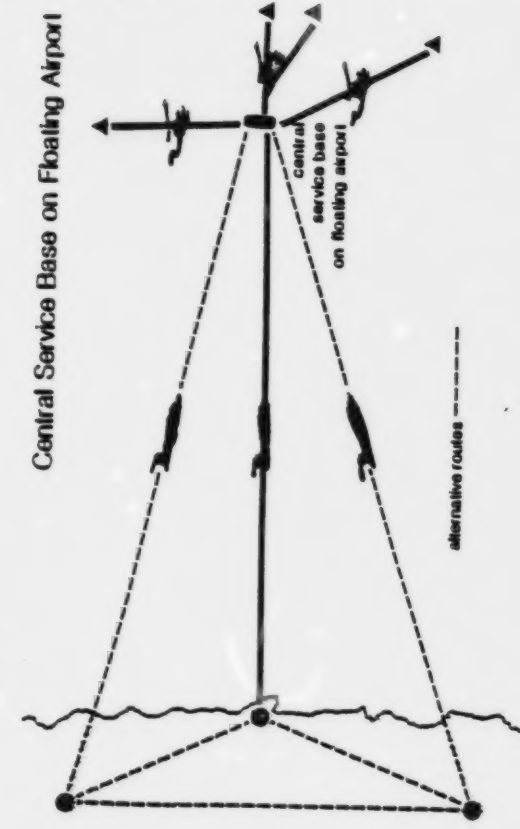
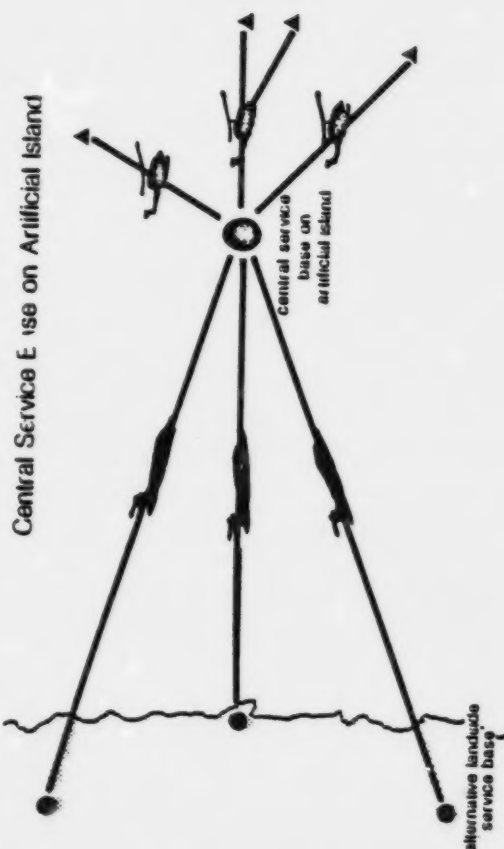
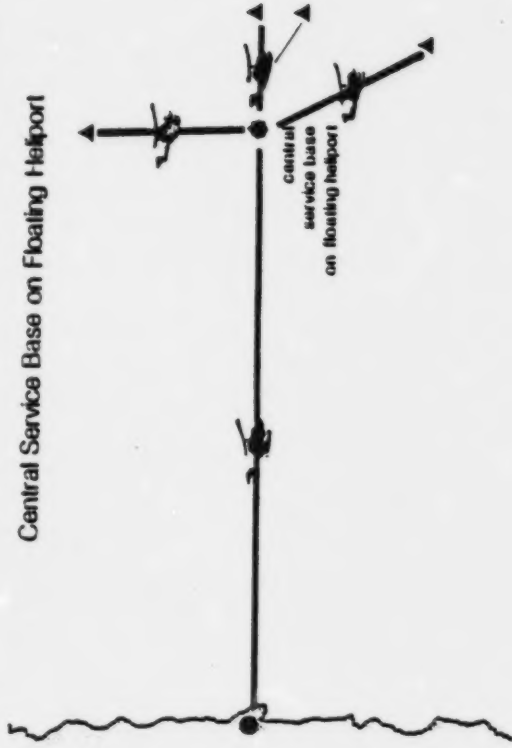
This alternative would involve a shuttle service utilizing a larger passenger capacity helicopter to provide a shuttle service to an artificial island based heliport or offshore heliport. The heliport could be part of an existing facility, a new artificial island, or part of a larger STOLport complex.

Dispersion of its passengers beyond the heliport to individual rigs would be conducted by smaller helicopter as a loop service or possibly by a suitable marine vessel.

This facility would be designed and electronically equipped to qualify as an alternate IFR heliport.



Central Service Base on Floating Heliport



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OPTIONS FOR OFFSHORE RESUPPLY

figure 17

Central Service Base on Floating Heliport

A shuttle service by large, shore based helicopters would serve a floating offshore heliport and would interface with the smaller helicopters providing a loop service to a number of rigs or a shuttle service to individual rigs. The landing limits on the main platform would be lower than those likely attainable on the individual platforms.

Employees could be transferred directly from the primary shuttle to the local service or could be held on the facility during periods of adverse weather in order to take advantage of short weather breaks as they develop. Marine vessel backup for offshore distribution could be provided to reduce delays in the secondary helicopter systems.

Central Services Base on a Floating Airport

This concept involves the introduction of a shuttle service by shore based fixed wing aircraft such as the Dash-7. The aircraft would fly a shuttle service between the land based airport and a floating STOLport, interfacing with smaller helicopters for employee transfer between the individual rigs and the STOLport.

Helicopter connections could be a loop service to a number of rigs or a shuttle service to individual platforms as for the floating heliport concept.

The introduction of supplementary fixed wing aircraft service linking more than one shore based airport to the STOLport, with subsequent connection to the offshore platforms would also be an option.

As is the case for the floating heliport, the secondary transfer service to the platforms could be provided by suitable marine vessels either on a regular basis or as backup during poor weather.

5.4 Subsequent Developments

The preliminary analysis indicated that the viability of the offshore artificial island concept was highly site dependent, and could not be advanced as general solutions to meet all the requirements within the three geographical areas.

A bottom founded gravity base platform having more general application, was substituted for the artificial island based heliport scenarios. However, the Virgin Rocks artificial island concept was retained.

The preliminary analysis also showed that the Seaforth Maritime Semi-submersible floating STOLport concept might not be justifiable because of low forecast traffic volumes. A floating STOLport barge concept which is cheaper to construct was introduced. This concept had the further advantage that it could provide a crude oil storage capability at the production site, which if utilized, could help defray the operating costs.

The study of the operating environment and related air navigation and landing aid requirements also indicated that there was a high probability that floating STOLport and heliport might safely operate at lower ceiling and visibility minima than could the helipads at the individual drill rigs and production platforms. As a consequence, there would be times when the primary shuttle could operate, but when the secondary helicopter service could not. The option of providing a marine service utilizing marine vessels of the submersible catamaran type was introduced to either substitute for, or to provide backup service to the offshore based helicopters.

Consideration of the concept of a floating hotel or floatel associated with either the floating heliport or STOLport was discontinued as

little requirement could be identified for this facility in the context of Canadian east coast offshore operations for the foreseeable future.

Detailed analyses of passenger transit options are provided in Sections 7.0 and 10.0

6.0 ROTARY WING AIRCRAFT

6.1 Selected Rotary Wing Aircraft Characteristics

Five types of helicopters examined for the purposes of this study were:

- | | |
|------------------|----------------------------------|
| o Sikorsky S-76 | o Aerospatiale AS332L Super Puma |
| o Sikorsky S-61N | o Boeing Vertol 234LR Chinook. |
| o Bell 214ST | |

The first four aircraft listed are currently in use for passenger shuttle operations off of Canada's east coast, all reporting accident free safety records. Although included in the data for cost comparison purposes, the Chinook is not yet employed for this use in Canada but it is certified for military transport use. The Chinook is operating in the North Sea presently, carrying up to 44 passengers per trip to various fields including Brent which is located 298 nm from its shore base at Aberdeen Scotland. Comparisons of characteristics such as range and payload capacity are itemized on Table 14 and 15.

Concern is being expressed over the capability of rotary wing aircraft to economically meet future requirements for offshore resupply due to high operating costs and capacity limitations, particularly as operating ranges increase. Improvements in weather related service reliability would also be welcomed by operators, particularly those improvements which could be implemented in the short term. Taking these considerations into account, research was carried out to identify and compare the capabilities and limitations of the five representative types of aircraft; review the current state of the art and scope for technological advancements for these and other helicopters; and determine the potential for future improvements to the basic shuttle service both in terms of equipment improvements and in supporting infrastructure development.

As can be ascertained from Table 14 and 15 the optimal choice of helicopter varies depending upon the passenger capacity required and the stage lengths to be flown. The AS332L Super Puma has greater passenger payload capability and greater range for IFR operations at economical

speeds than some of the earlier machines. Its future competition at the longer stage lengths appears to be the Boeing Chinook, but this latter aircraft may provide more capacity than can be effectively utilized in the short term in the context of east coast operations. These apparent technological advantages of the heavier, larger aircraft must, however, be weighed against economic considerations such as capital costs, operating and maintenance costs, reliability, manufacturer service response and passenger demand, to gain a balanced perspective on aircraft suitability. In both the Canadian and North Sea resupply situations a variety of aircraft are now utilized simultaneously and this situation is expected to continue.

The methodology employed for estimating helicopter costs in the study involved the development of a composite cost for each geographical area based on the payload/range/operating cost characteristics of the representative helicopters. In some instances, a specific helicopter type was selected to illustrate a particular point, but no attempt was made to identify the preferred helicopter for any particular service.

The estimated operating costs of the five selected helicopters are shown on Table 16 and detailed later in this section.

6.2 Rotary Wing Aircraft Developments

Much of the interest regarding future helicopter requirements in support of the offshore petroleum industry appears to centre on two major issues:

- o an apparent need for the replacement of the Sikorsky S-61N, although it is generally agreed that this helicopter is likely to be in service for the rest of the decade, if not well into the 1990's. Although its speed is slow relative to many of the newer technology helicopters this disadvantage appears to be offset by its spacious cabin, operational flexibility, very good reliability and low operating cost;

Feature	Sikorsky S76	Sikorsky S61N	Bell 214 ST	Aerospatiale AS332L Super Puma	Boeing BV234LR Chinook
Seating Capacity (persons/max) crew/passengers	2/12	2/26	1/17	2/21	3/44
Maximum Cruise Altitude (metres)	1890	N.A.	3170	2100	4570
Maximum Take Off Weight (kilograms)	4672	8620	7938	8350	22000
Fuel Capacity (litres)	1060	N.A.	1647	2060	7949
Maximum Cruise Speed (knots)	155	130	141	163	150
Maximum Still Air	470	337	404	810	655

Rotary Winged Aircraft Capability⁹

Table 14

- o the all-new helicopter of the future should be capable of carrying 25-30 passengers with an IFR radius well in excess of 250 nautical miles, at about 150 knots speed, with a genuine all-up-weight single engine landing capability, and with full engine, blade and airframe de-icing. With regard to this new aircraft's range, as countries extend their search for offshore hydrocarbon resources to even more remote areas, distances in excess of 500 miles from shore may be required.

In both the North Sea and on Canada's east coast, much of the helicopter equipment, apart from the S-61N, is relatively new. Thus the timing of and numbers of entirely new technology helicopters likely to be required is uncertain, other than as potential replacements for the S-61N. Should the activities on Canada's east coast move to a large

⁹ Taylor, J.W. (Ed.), Jane's All the World Aircraft 1982-83, London, and McGraw-Hill, Aviation Week & Space Technology, Vol. 116, No. 10, New York, March 8, 1982.

CHARACTERISTICS	TYPE OF HELICOPTER				
	S-76	S-61N	214ST	AS332L	BV234LR
Preferred Cruise Speed (knots)	135	110	130	135	135
Max. IFR radius of action at economical speed (nm)	265	225	250	300	335
Actual seating capacity used for east coast operations	8	17	16	16	-
Passenger/payload range with IFR reserve (nm)	people*	people*	people*	people*	people*
100	11	23	16	22	44
150	8	19	16	22	44
200	6	15	13	22	44
250	4	-	10	16	44
300	-	-	-	13	25
Distance/flying time range**	minutes	minutes	minutes	minutes	minutes
50 nm	22	27	23	22	22
100	45	55	46	45	45
150	67	82	69	67	67
200	89	110	92	89	89
225	100	124	104	100	100
250	111	-	115	111	111
275	-	-	-	123	123
300	-	-	-	133	133

Rotary Winged Aircraft Characteristics

Table 15

- * 100 kg average for passengers luggage and immersion suit.
 ** Does not include manoeuvring time.

	S-76	S-61N	214ST	AS332L	BV234LR
<u>1. Capital Cost</u>					
o 1982 aircraft cost	2,750,000	3,000,000	4,880,000	5,000,000	16,640,000
o Spares	340,000	380,000	610,000	630,000	2,080,000
o Total capital	3,090,000	3,380,000	5,490,000	5,630,000	18,720,000
<u>2. Fixed Charges</u>					
a) <u>Personnel</u>					
o Pilots	160,000	160,000	160,000	160,000	160,000
o Technicians	144,000	144,000	144,000	144,000	144,000
o Extra crew members	-	-	-	-	72,000
o Dispatcher/Office	40,000	40,000	40,000	40,000	40,000
Sub-total	344,000	344,000	344,000	344,000	416,000
b) <u>Depreciation</u>	233,750	255,000	414,800	425,000	1,414,400
c) <u>Insurance</u>	165,000	180,000	292,800	300,000	998,400
d) <u>Interest Charges</u>	173,800	190,125	308,800	316,700	1,053,000
e) <u>Management Charges</u>	300,000	300,000	300,000	300,000	300,000
f) <u>Profit</u>	297,000	303,500	402,900	432,000	1,040,000
o Total fixed per year	1,513,550	1,572,625	2,063,300	2,117,700	5,222,200
o Fixed per month	126,000	132,000	172,000	177,000	435,000
<u>3. Hourly Charge</u>	440	510	590	790	1,700
<u>4. Annual Cost for 1,000 hrs*</u>	\$2,132,080	\$2,408,530	\$2,916,540	\$3,239,540	\$7,723,740
<u>5. Average Cost per hour for 1,000 hours*</u>	\$2,132.08	\$2,408.53	\$2,916.54	\$3,239.54	\$7,723.74

Summary of Estimated Helicopter Costs

Table 16

* Includes: fixed monthly charge, hangarage, hourly charge (primarily maintenance), fuel and oil and landing fees. Cost of immersion suits for passengers, is not included.

scale production levels, it is conceivable that there will be scope for the introduction of a number of helicopters with a 25-30 seat capacity, displaying good payload/range capability (approximating 250 nm radius). It is questionable whether any new helicopter will be designed strictly for a civilian application. The very high cost of developing a new helicopter, in excess of \$150 million, indicates that a strong military requirement must exist first, and that civilian versions will result as derivatives. While this cost appears to be high, it is modest when compared with the cost of some of the alternative solutions considered in this study. Outlined here are several of the future prospects with regard to new helicopter technology:

Westland WG-30 This aircraft was introduced recently into commercial service for onshore operations only. It has been examined for offshore applications but its payload/range characteristics do not appear to be suitable. With a full load of 15 passengers. Its IFR radius increases to about 175 nm under IFR conditions. There is some discussion about re-fitting this aircraft with newer and more powerful engines, which may only increase its IFR range to 80nm at full payload.

Augusta AS-61N1 This model, built by Augusta of Italy, is based on modification of the Sikorsky S-61N. It retains all of the proven, reliable features of the Sikorsky model but is lighter (shorter fuselage) and has greater payload than its predecessor. Range for offshore operations is planned to be about 270 nm with a 15% increase in fuel capacity. It is not certain whether it has sufficient operational advantage over the current Sikorsky aircraft to warrant the additional expenditure for a new version. Its projected cost is \$7.4 million (Canadian 1982). There is some thought of refitting the aircraft with a new engine, which is projected to improve its range capability and to lower its operating cost.

E-H 101 This new, medium weight, multi-purpose helicopter is being developed jointly by Westland Helicopters Ltd. and Augusta of Italy, and is being targetted for a number of military and civilian applications. With first deliveries planned for 1989, the aircraft is attracting interest as a replacement for the S-61N. With a full load of 30 passengers, the IFR radius is about 250 nm; 20 passengers can be carried for an IFR radius of 350 nm. Its cost will likely be in excess of \$8.0 million.

Sikorsky UH-60A Black Hawk For some time it was felt that Sikorsky might be re-entering the market with a Mark 3 version of the S-61N. Speculation indicates that Sikorsky may be prepared to adapt the Black Hawk to a civilian version possibly designated as the S-78. There appears to be no solid evidence for this move by Sikorsky. With eleven combat equipped troops on on-board (probably more civilian passengers), the military version has an operating radius of about 200 nm; this can be extended to over 400 nm with addition of an in-cabin fuel tank. Installation of this tank, however, leaves little space for extra passengers.

Boeing Vertol 234LR Chinook Although included in the research study, the Chinook is not as yet part of the Canadian offshore market and in the Canadian context can be viewed as future technology. Clearly, this aircraft appears to have had a significant effect on offshore operations in the North Sea. Although an expensive aircraft, it has proven to have excellent payload/range capability, being able to fly directly on an IFR basis with full passenger loads to all areas which it currently serves. If introduced to the east coast shuttle operation, consideration may be required for offshore helideck upgrading.

Tilt Wing/Rotor Technology¹⁰ Of interest to offshore aviation circles is the technology of tilt wing aircraft being researched by

¹⁰ Thomason, T., ICAO Bulletin, Vol. 38, No. 8, Montreal, August 1983

Bell Helicopter, Boeing Aircraft and NASA presently. The concept combines the vertical flight capability of a helicopter with the forward speed of conventional aircraft. One model now being considered for future civilian application in the U.S.A. is the Bell XV-15, which has a design capacity of 16 passengers, a cruise speed of 500 km/h, with a maximum cruise speed of 556 km/h at 4900 A.S.L.

After take off, the rotors are tilted forward in order to operate as propellers. This rotation, which takes 15 to 20 seconds to complete, results in forward motion which transfers lift to the wing. As a result, the aircraft is capable of accelerating to higher cruising speeds than those attainable by a helicopter at a similar power level.

Comparisons of characteristics such as cruising speed and efficiency with those of a turbo-prop airplane of the same gross weight and engine type indicate that the XV-15 achieved 97 percent of the specific range of the turbo prop at greater speeds (100 km/h faster). This was almost twice the speed and range capability of conventional helicopters.

The XV-15 has also been designed with emphasis on greater failure tolerance and operating reliability. In the event of total engine failure, the tilt rotor aircraft initially has the glide capability of fixed wing aircraft and the capability to convert to the helicopter mode for final auto-rotation and descent. Weather related difficulties are expected to be less of a problem for this aircraft than for a helicopter since it performs as a fixed wing aircraft including the ability to avoid inclement weather conditions. Overall flying time in the context of East Coast operations would be less, so that short weather windows should be less of a problem than for helicopters.

Although its purchase cost is expected to be 30 percent higher than that of a helicopter, its operating cost is expected to be significantly lower as shown in Figure 18. This is due to such factors as the reduction in block hours of operating time, and the resultant lower fuel consumption per mission flown. Passenger/km costs as compared to those of STOL aircraft are expected to be higher, however, due to the higher costs.

However since the aircraft would have the capability to travel directly from a shore base to an offshore rig the actual cost per trip/passenger could be competitive for small passenger loads. Maintenance costs are expected to be lower than for helicopter due to less vibration and greater component reliability.

Passenger comfort is expected to be comparable to the level experienced on conventional aircraft, an improvement over the cabin environment of conventional helicopters.

As the aircraft is still in the experimental stage it is not known what the limiting wind conditions would be for final approach and landing at offshore oscillating platforms exposed to high wind and low visibility conditions.

Perceived advantages to the offshore industry in introducing this type of air service may be:

- o the capability of permitting crews to live in more remote or desirable communities during off duty periods, which also could include a city centre shuttle service;
- o the capability of providing air transportation between centres where conventional airport facility construction is expensive or prohibitive;
- o the elimination of helicopter/air crew transfer staging points;
- o air transport to rigs at greater distances offshore.

The major disadvantage for this aircraft is, unfortunately, development timing. This concept, while possibly useful, if not certified for commercial use making short term planning problematic. Another disadvantage - passenger capacity the prototype aircraft is at the low end of the operating range for helicopters and is one third that of the Dash 7. Research and the testing of similar aircraft designs, ranging in size from 25 to 100 passenger capacity continues through the efforts of Bell, Boeing and NASA.

The concept therefore, while interesting in the longer term, does not provide a solution in the short term. Nor has the development of the aircraft reached the stage where its viability for off-shore applications can be reliably predicted.

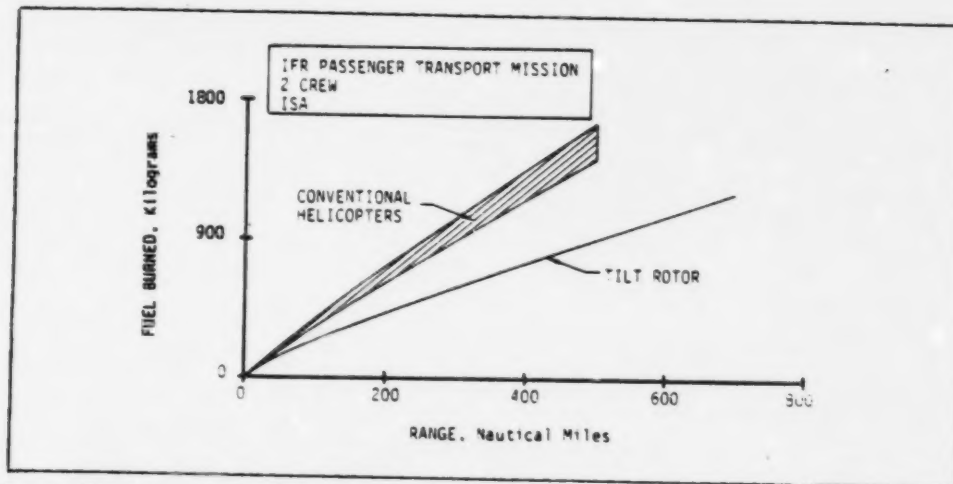
Still in the preliminary design stage is the JVX derivative tilt rotor aircraft, estimated to cost \$12.5 million (U.S. 1984 \$).¹¹ This aircraft has a long range cruise speed of 230-260 knots (VTOL/STOL) and may carry between 90 to 120 passengers depending upon the VTOL/STOL mode employed. Although it is expected to cost 20% more than a conventional helicopter of comparable size it is expected to be 60-70% more cost effective in operating costs per block hour due to greater fuel efficiency and payload capacity.

As with the XV-15 the JVX derivative will be unavailable for offshore application in the short term, a commercial version proposed by the mid 1990's.

The fuel consumption comparison between the tilt rotor aircraft and helicopters is shown on Figure 18 and a cost effectiveness comparison is given in Table 17.

¹¹ Sloan, W., Bell-Boeing Joint Project, November, 1983.

The passenger capacity of the aircraft is significantly higher than that which can be effectively utilized for the offshore shuttle operations examined in this study.



Fuel Consumption Comparison
Helicopter vs. Tilt Wing Aircraft
(16 passenger Aircraft Seat Capacity IFR Mission)

Figure 18

Distance (nautical miles)	Cost/Seat/n.m. - \$ U.S.		Normalized Cost	
	Helicopter*	XV-15	Helicopter	XV-15
50	.65	53	1.09	0.88
100	.62	51	1.03	0.85
200	.61	49	1.00	0.82
300	.59	48	0.98	0.80
400	.71	47	1.18	0.78
500	.88	46	1.47	0.78
600	-	45	-	0.75
700	-	50	-	0.83

Cost Effectiveness Comparison
Helicopter vs. Tilt Wing Aircraft

Table 17

* "Average" size helicopter (not one particular model, but a combination)

Advanced Technology Several additional projects are underway in the development of advanced helicopter designs, primarily based on major military programs. Their future potential for commercial applications cannot be reliably determined at this time. Examples of advanced technology include:

- Sikorsky's advanced blade concept (ABC) offers 250 knot speeds combined with compact dimensions for shipborne operations. It will be capable of operations of up to 7600 m of altitude. The XH-59A has been developed as an ABC testbed;
- the X-wing concept, in which the rotor is slowed, then stopped at speeds between 170 and 250 knots to form an X-platform wing with slender lifting panels. The aircraft can then theoretically reach a 500 knot airspeed, driven by an integrated lift/propulsion powerplant. Work is proceeding in the U.S. on developing a manned X-wing demonstrator.

6.3 Navigational Aids - Aviation

At present due to the low volumes of air traffic involved, there are no formal en route navigation, communication or air traffic control services procedures or systems in effect for aircraft operating to and from offshore platforms. Interim procedures have been established by agreement between carriers and controllers based on the use of the following facilities and practices:

- o VOR/DME¹² within range of shore based coverage
- o NDB¹³ airborne radar/transponders in vicinity of rigs
- o routes filed and approved by mainland based Transport Canada air traffic controllers, and
- o positive radio communication between aircraft and rigs.

¹² VOR/DME Very High Frequency Omni-Directional Range/Distance Measuring Equipment

¹³ NDB Non Directional Beacon

Work is progressing on the possible use of long range navigation systems, OMEGA or LORAN-C, as primary navigation aids. Their use, other than as a secondary aid, has not, however, been approved by Transport Canada to date. Although some of the carriers favour LORAN-C because of its lower cost and perhaps greater precision, the coverage by ground stations may not be adequate, and OMEGA will probably also be required.

A LORAN-C Centre, issuing marine navigation advisories only, is located at Cape Race Newfoundland, and Vessel Traffic Management Centres are situated at the following sites, all operated by the Canadian Coast Guard:

- o Eddy Point, Nova Scotia, near Cape Canso
- o Port aux Basques, Newfoundland
- o Placentia Bay, Newfoundland
- o St. John's, Newfoundland

In terms of future enroute procedures, analysis of potential traffic volumes shows that a substantial increase in aircraft movements will lead to the requirement for a more structured NAV/COM/ATC system. Such a system could be based on a number of possible approaches:

- o A parallel track system, similar to that used in the North Sea, with initial separation by VOR/DME, followed by enroute navigation using a long range navigation facility (in the North Sea, DECCA, a U.K. developed system, is used as the enroute navigation aid):
- o Possible installation of VOR/DME's offshore, either on Sable Island in the case of the Scotian Shelf, or on a floating rig, heliport or STOLport in the cases of Hibernia and the Labrador Sea. The estimated costs for an offshore VOR/DME facility are shown in Table 18;
- o Installation of offshore peripheral (PAL) communication facilities to ATC centres to improve air traffic control procedures in the vicinity of the rigs. A representative system might include

VHF-AM¹⁴ and UHF-AM¹⁵ radios at the PAL site for communication with the helicopters and other aircraft operating in the area. The link to the mainland ATC facility could be by high-power HF-SSB¹⁶. Estimated costs are shown on Table 19.

- o Installation of a dual channel Microwave Landing System (MLS).

1. Full dual channel SVOR 100 watts, including antenna, DME mount facilities and counterpoise	\$150,00
2. Full dual channel high power DME, including built-in test unit and antenna	90,000
3. No-break power supply, including ni-cad batteries	40,000
4. Diesel generator	62,000
5. Shelter, including air conditioning, heater and electrical wiring	23,000
6. Spares	10,000
7. Test equipment	5,000
8. Installation labour	<u>30,000</u>
Sub-Total for each land-based facility	\$410,000
9. Additional cost for special requirements on floating STOLports, helicopter rig	<u>80,000</u>
Total for each floating installation	\$490,000 =====

Estimated Cost of Offshore VOR/DME Installation
(\$ Canadian)

Table 18

- 14 VHF Very High Frequency.
- 15 UHF Ultra High Frequency.
- 16 HF-SSB High Frequency - Single Sideband.

1. <u>OFFSHORE FACILITIES (ON NATURAL ISLAND OR RIG/HELIPORT/STOLPORT)</u>	
<u>VHF-AM Facility:</u>	
including two radios, antenna, shelter, spares, installation	\$ 45,000
<u>UHF-AM Facility:</u>	
including two radios, antenna, spares, installation and housed in same shelter as VHF-AM radios	35,000
<u>HF SSB Link to Shore:</u>	
including two radios, antenna, spares, installation and housed in same shelter as VHF-AM and UHF-SM radios	50,000
<u>Diesel Generator:</u>	
2. <u>ONSHORE FACILITIES</u>	
<u>Two HF-SSB Radios:</u>	
installed including spares, antenna, shelter, connection to power supply and landlines to the air traffic control centre	120,000
Total per one hydrocarbon area	\$312,000
NOTE: No cost allowance included for the acquisition of onshore property for navaid siting or special technical requirements on offshore installations.	

Estimated Costs for Off-Shore Peripheral (PAL) Communications Facilities

Table 19

6.4 Approach/Departure Procedures and Limits

At land-based airports, currently approved operating minima for helicopters operating to offshore sites are at what is termed "operational Category I". The limits are set at 60m ceiling and/or 400m visibility (400m RVR)¹⁷ based on the use of a front-course Instrument Landing System approach with both azimuth and glidescope in operation.

¹⁷ RVR Runway Visual Range

The weather minima for IFR approach at the rigs and probably the floating STOLport is set at 45m ceiling and 800m horizontal visibility, based on an approach using NDB and airborne radar, combined with positive identification of the rig by a transponder beacon located on the rig. In this approach, visual contact with the water must be established at no less than 3.2 km back from the rig on final approach, for the approach to be continued to the visibility limit. In circumstances of minimum visibility, the rig's support ship or tender is often stationed on the approach track at the visibility limit to provide the helicopter with a more positive radar indication of the distance from the touchdown point on the rig (used as a form of middle marker indication). The direction of the let-down and approach procedure is varied to allow the helicopter to make its approach into the wind to the greatest extent possible.

Tests are now underway by the helicopter operators and Transport Canada to develop an offset radar approach, which is planned to reduce the horizontal visibility minimum to 400m.

6.5 Potential for Approaches to Lower Limits

As noted in Section 3, periods of weather below Category II limits can be anticipated with some regularity. As well, there are often times in the vicinity of the rigs, and particularly at Hibernia during the summer, when only relatively narrow "time windows" (2 to 3 hours) of acceptable flying weather may occur, based on current IFR minima.

These adverse weather conditions frequently cause delays in the helicopter flights to the rigs. The impact of these delays is discussed in Sections 4 and 10 of this study.

Present minima for offshore operations place the aircraft at about 15 to 20 metres above the helideck and at 800m horizontal visibility. The height above the helideck is below the Category II height minimum, and

thus the next step in a reduction in landing limits would be approaching or equivalent to Category III(a) with future reductions to Category III(b) or III(c) limits (zero-zero).

In discussions with avionics and helicopter manufacturers, it has been ascertained that from the point of view of electronics equipment Category III operations are within the bounds of technical feasibility. The introduction of appropriate electronic and helicopter handling procedures such as those listed would be a necessary minimum to permit Category III type or, fully automatic landings:

- o A dual channel MLS with sufficient system redundancy to meet Category III requirements.
- o A co-located precision DME.
- o An integrated helicopter flying control system which will allow a fully coupled approach over the full speed range of the aircraft and which will permit a transition to hover at 2.4 metres or lower, or possible full coupled touchdown on the helideck.
- o Appropriate MLS and precision DME receivers and instrumentation, as well as a radio altimeter, on-board the helicopters.

Precision DME of appropriate accuracy is under development and is expected to be available in about three years time. The required flight-control system could be similar to the Collins HFCS-800 system being developed for the U.S. Coast Guard. This system is expected to receive FAA certification and is designed to progress the helicopter to a hover at 15 metres radio altitude. The co-located MLS/precision DME facility would have to be mounted on a turntable, and in the case of an installation on a floating rig, heliport or STOLport, the installation would require a gyro-stabilized platform.

Table 20 shows representative costs for the electronic aids and platforms, for research purposes. It will be noted that costs widely exceed those normally quoted for MLS installations. However, the special requirements associated with Category III criteria imply

substantial additional costs and the requirements are complicated by the need to provide reliable signals from oscillating platforms.

In terms of the helicopter requirements, the potential appears to be somewhat less promising, at least in the near term than for fixed wing aircraft. For certification of Category III operations, [possibly limited to Category III(a)] a aircraft must have a totally fail-safe autopilot and flight control system. Also, during the final phases of approach to touchdown (say at altitudes of less than 30.4m above the touchdown point and at airspeeds of less than 40 to 50 knots), provision must be made to automatically avoid vortex ring/power settling conditions and to provide safe unabated descent to touchdown within the landing gear design impact limits. As well, adequate reserve power must be available to offset the effects of one engine failing during the latter stages of the final approach. These factors suggest that a completely new "new-generation" of totally-IFR helicopters will be needed to meet these goals.

The likelihood of certification of Category III approach procedures, particularly on vessels with significant superstructures such as jack-up legs and drilling derricks, is uncertain. However, because of the potential benefits involved the possibility for of improving reliability of service in IFR conditions warrant considerable attention being paid to additional research and analysis.

6.6 Helicopter Safety in Offshore Operations

Discussions with the Transport Canada Aviation Safety Bureau indicate that the east coast offshore helicopter shuttle operations are accident-free, to date.

This information is consistent with opinions available from the aircraft manufacturers and from the aviation industry generally. The

A. SURFACE INSTALLATION	
1. <u>Dual channel MLS</u> with sufficient redundancy to meet Category III standard	\$750,000
Spares: \$200,000 for one offshore site) or \$ 50,000 per site if a number of sites)	200,000
Test and special equipment	36,000
Turntable	100,000
Installation (assume done on re-fit at shore base)	150,000
2. <u>Precision DME</u> to 20 feet accuracy	250,000
Spares	50,000
Test equipment	6,000
Installation	50,000
3. <u>Gyro-Stabilized Platform</u>	up to 2,000,000
TOTAL OFFSHORE	\$3,592,000
B. AIRBORNE EQUIPMENT PER AIRCRAFT	
1. Dual MLS receivers and instrumentation	\$20,000
2. Dual precision DME	20,000
3. Dual radio altimeters	30,000
4. Test equipment	40,000
5. Installation	10,000
6. Helicopter flight-control system (similar to Collins HFCS-800)	50,000
TOTAL AIRBORNE EQUIPMENT	\$170,000

Representative Costs for Precision Electronic Aids to a Category III Standard (\$ Canadian)

Table 20

excellent safety record of these operations can be attributed to a number of factors:

- o generally new and well equipped and maintained helicopters
- o careful supervision of flight operations by on-site management
- o the use of highly experienced technical staff and aircrew
- o thorough initial and recurrent training
- o a cautious or low-risk approach to operations by the oil companies; in that delays due to adverse weather conditions appear to be accepted as part of normal operations in the east coast environment
- o relatively low levels of activity.

Examination of the North Sea operation, where more information is available from several sources indicates that there have been a number of accidents over the past ten years since helicopter operations began. Information from readily available sources is summarized in Table 21.

Relative to overall helicopter operations in Canada and the U.S., the safety record on the Canadian east coast and in the North Sea must be considered excellent. Taking all Canadian helicopter operations into account, the record is not considered to be as favourable:

- o in 1972 there were almost 33 accidents per 100,000 flying hours;
- o by 1978 it had declined to a rate of about 25;
- o in 1981 it was still at 25, and in that year, for every 9.5 helicopters in the field, one had an accident.

1972 - 1979	NORWEGIAN SECTOR	BRITISH SECTOR
Number of accidents	5	13
Total flying hours	199,490	434,000
Accident rate/100,000 flying hours	2.5	3.0
Number of passenger injuries/ fatalities	34	1
Injury/fatality rate/100,000 flying hours	17.0	0.2
1980 - 1982	NORTH SEA (total)	
Number of Accidents	10*	
Total fatalities	40	
1972 - 1982		
Total Number Accidents	28	
Total Number Fatalities	75	

North Sea Helicopter Accidents 1972-1982¹⁸

Table 21

* it was reported that these accidents resulted from mechanical problems rather than from operating procedures.

The total U.S. fleet, achieved a better record. In 1981, it recorded an average rate of 13 accidents per 100,000 hours, while members of the Helicopter Association International (HAI) fared better at a rate of just over 5. Interestingly, Okanagan Helicopters, one of the major Canadian offshore operators, recorded a reported rate in 1981 of about 5.5 accidents from all operations. Noting that Okanagan has a 30% share of the overall Canadian market, the 1981 industry-wide average rate of 25 raises concerns regarding the safety records of some of the residual operators.

¹⁸ Sorensen, B.M., et al, STOLport An Alternative Offshore Transport System OR22121281.18.01. The Ship Institute of Norway, Marine Technology Centre, Trondheim, December, 1981.

Many of the non-offshore operations in Canada are in frontier areas and where the flying is typified by activities in remote areas for long periods, with no supervision. and little or no refresher training. This clearly contrasts with efforts taken in the offshore operation and is claimed by many to be the major cause of the high accident rate in non-offshore activities. A graphic summary of helicopter accident statistics by specialty is provided in combination with those for fixed wing aircraft in Section 8.

6.7 Icing Conditions and Helicopters

As the demand for IFR operations by helicopters has grown, in-flight icing has been increasingly identified as a major operating limitation.

Current commercial interest in blade de-icing systems, or for greatly improved ice detection equipment, stems from the need to service offshore oil rigs in inclement weather, where the lack of a vital part or component can cost a drilling company heavily in lost drilling time. Also there is a continuing need to address serious medical emergencies or evacuations.

The problem is pressing off of the east coast of Canada, where the combination of a high incidence of IFR weather and extended periods of below freezing temperatures is a common occurrence.

Icing on helicopters is generally considered to be a more serious problem than on fixed wing aircraft, for a number of reasons:

- o ice-induced engine failures can occur with little or no warning;
- o rotor blade icing can cause complete loss of control in a matter of seconds and can completely degrade the auto-rotation capability to the point where a safe landing cannot be made in the event of total engine failure;

- o asymmetrical shedding of main and tail rotor ice can cause seriously high vibration levels and aircraft damage;
- o increased power requirements due to additional drag of the rotor system;
- o restricted airspeed, premature blade stall, and significantly reduced range and endurance.
- o de-icing systems on fixed wing aircraft can be more readily provided;
- o fixed-wing, pressured aircraft can sometimes avoid freezing zones by flying at altitudes higher than those that can be attained by helicopters.

Extensive work has been carried out over the past few years in an attempt to reduce or resolve the icing problem, but, while a number of de-icing systems have been developed, none appear to be universally certifiable for civilian operations. As well, offshore operators are sometimes reluctant to invest in expensive on-board systems that impose substantial weight penalties particularly in situations where they are operating at extreme payload/range capability of the aircraft. As a consequence, operators are interested in equipment that can be removed during warmer weather, to prevent fuel wastage and improve payloads. For example, the de-icing system available for the AS332L Super Puma weighs about 136 kg. The weight penalty is equivalent to almost 2 passengers or to a 20 nm reduction in operating radius at economical cruising speed.

Presently, helicopter flights during icing conditions are not permitted in Canada or the United States but are allowed in France and the United Kingdom. Flying during icing conditions over the North Sea is permitted subject to these rules:

- o no greater than 0.35 grams of liquid water content (LWC) per cubic metre of air;
- o air temperature at flight level no lower than -5°C;

- o at least a 60 m ceiling over the water;
- o an icing rate indicator must be installed.

6.7.1 Technological Advancements¹⁹

Some of the current work being carried out to overcome icing problems includes the following:

- o Leigh Instruments of Canada has developed a system with two separate units that warns of ice accumulation and the other assists in blade de-icing. The ice detection unit (IDU) is being used in North Sea operations and in tests involving an Aerospatiale AS332L Super Puma in eastern Canada.

The IDU, simulates the conditions in which the rotor blades are operating, measures the rate of ice build up over a series of short discrete time intervals and converts the results into a liquid water content (LWC) measurement, which is continuously displayed to the pilot as grams per cubic metre of air.

The second, or integrating rate unit (IRU), integrates LWC information from the IDU over time, to produce "ice units", which can be programmed to:

- determine how much more ice can be taken on by the aircraft before some corrective action must be taken;
- manage the de-icing of the main and tail rotor blades at pre-selected ice-buildup levels and de-icing rates.

In the United States, two Army helicopters, the Sikorsky UH-60 Black Hawk and Hughes AH-64 Apache, are reported to be equipped with approved de-icing equipment. The Black Hawk is of particular interest as it is the closer to being operational. The system is relatively light, only adding about 31.8 kg in weight to the Black Hawk, and requires no additional electrical power. This system, however, is designed specifically for a military application and may not meet civilian requirements in terms of system redundancy and adequate performance at specific combinations of water content and temperature.

¹⁹ Rotor & Wing International, June 6, 1983.

Sikorsky is in the process of developing a de-icing system for the S-76 that is expected to meet civilian standards and be certified by 1985. It is based on the technology of the Black Hawk and is expected to add about 68 kg to the weight of the S-76. Forty-five kilograms of weight will be removable for summer operation. It is expected to cost around \$200,000 (U.S. 1983) per installation. It is primarily intended for use on corporate aircraft where payload/range considerations are not as critical. Helicopters so equipped can then compete effectively in terms of safety with corporate fixed wing aircraft.

Other developments include:

- o In Britain, the Civil Aviation Administration (CAA) has approved use of the Sikorsky S61 at altitudes between 150m to 1520m over water in temperatures down to -6°C. To date no problems have been reported.
- o In January 1983 "moderate icing tolerance" tests were held utilizing the Bell 214ST aircraft in Scotland, in support of CAA approval in 1983, and ultimately FAA certification.
- o The FAA/NASA/U.S. Department of Defense is currently studying atmospheric icing at altitudes below 3000m, with study results expected in late 1983.
- o Boeing has developed a new electrical heating system for its Chinook helicopter for testing in December 1983. The concept involves the use of heating blankets on the leading edge of each fiberglass blade, bonded during manufacture.
- o Use of studded tires or chains on helicopters to assist with landing is also under consideration.
- o Use of chemical de-icing agents, microwave or vibratory methods of de-icing are considered less effective.

ITEM	COMMENTS	COST
Ice Detection Unit (IDU)	Complete with meter, installed	\$16,000 (Can)
Integrating Rate Unit (IRU)	Installed	\$8,000 (Can)
De-Icing System (certified in France)	For use in Aerospatiale AS332L Installed	\$298,200 (US)

Estimated Costs of Helicopter
Ice Detection and De-Icing Equipment (1983)

Table 22

6.8 Helidecks or Helipads Design Characteristics

Design standards for rotary winged aircraft landing areas have been produced by Transport Canada (TP2586) but are currently being updated. Basic facilities design information for the five types of helicopters reviewed is presented as Table 23. To date, Transport Canada has not specified safety margin requirements related to rejected take-off, or other IFR criteria, for helipad/helideck design.

FACILITY	HELICOPTER TYPE	CHARACTERISTICS
Helideck (for single main Rotor Helicopters)	S-76	Large enough to contain a circle of this diameter.
	S-61N*	68.3 feet 20.7 metres
	214 ST	94.7 ft.* 28.8 m
	AS332L	80.9 ft. 24.6 m
		79.9 ft. 24.3 m
Helideck (for twin tandem Rotor Helicopters)	BV234LR	Large enough to contain a rectangle with these dimensions. 89.1 x 74.3 ft. 27 x 22.5 m
Heliport	S-76	Minimum size of landing area to be 150% of overall length of the design helicopter plus a further 25% of the overall length on each side as a safety margin.
	S-61N	118.2 ft. 35.9 m
	214 ST	163.8 ft. 49.7 m
	AS332L	140.0 ft. 42.5 m
	BV234LR	138.3 ft. 42.0 m
		222.8 ft. 67.7 m

Helideck and Heliport Minimum Dimensions

Table 23

* Critical helicopter

6.9 Helicopter Cost Factors

The cost estimates contained in this study are based on information obtained from a number of sources including equipment manufacturers, Canadian helicopter operators and contracting oil companies. The defined costs are summarized in Table 24.

Capital Cost

The cost of helicopters and spares for selected equipment are listed in Table 24. These costs were based on 1982 costs in U.S. as supplied by manufacturers, and assume a conversion rate of \$1.00 (US) = \$1.25 (Cdn).

Spares were estimated to cost 12.5% of the capital cost of the airframe based on a range in practice of 10% to 15%.

HELICOPTER		SPARES	TOTAL INVESTMENT
S-76	\$2.75	\$0.34	\$3.09
S-16N	3.00	0.38	3.38
214ST	4.88	0.61	5.49
AS332L	5.00	0.63	5.63
BV234LR	16.64	2.08	18.72

Helicopter Costs (\$ Million (Canadian) 1982)

Table 24

Fixed Charges

These costs are developed on the basis of the following assumptions:

a) Personnel

The assumed annual salary including benefits for flight crews and support staff are shown in the following table:

Category	Annual Salary (\$1000)	Number Per Aircraft	Comment
Pilot (average)	40	4	400-500 hours annually
Technicians	36	4	Same as for pilots
Cabin Crew	18	2	For BV234LR only
Dispatcher/Office	20	1	

Assumed Personnel Salaries

Table 25

b) Depreciation

- o assume policy of 10% per year straight line method to 15% residual value on aircraft capital cost: factor therefore is 8.5% per year;

c) Insurance

- o assume 6% of the capital cost of the aircraft, as the annual premium to cover both hull and liability insurance;

d) Interest Charges

- o assume 75% of the cost of aircraft and spares is financed by long-term debt; thus average interest charge is 15% (assumed prime plus 3%) of one-half of the long term debt;

e) Management Charges

- o to include such items as base costs, special equipment installed in aircraft for the offshore operation (eg. Omega), head office management, initial and recurrent aircrew training: estimated at \$300,000 per year for all aircraft;

f) Profit

- o assumed at a target of 20% of the sum of all other fixed air carrier charge plus the variable charge per hour at an assumed minimum of 50 hours per month (600 hours per year).

Hourly Charge

Based primarily on direct maintenance costs incurred per flying hour, including:

- o parts and supplies consumed in day-to-day running;
- o engine overhaul provision;
- o main rotor replacement;
- o provision for dynamic components.

Labour is not included as a factor in the hourly charges but, rather is covered under fixed personnel charges.

A small additional allowance may be included by some operators in the hourly charge for foreign exchange fluctuations and early cancellations. Typically profit is included in the hourly charge. Some allowance for these factors is made by hourly charge estimates.

7.0 THE BASE CASE

7.1 Introduction

This chapter describes the methodology employed and the analyses carried out to determine the basic system for offshore employee air transportation, in which selected alternative air transportation system strategies were evaluated.

The base case strategy assumes the continuation of the present shuttle operation, transporting employees between the onshore supply bases and the offshore work stations by various types of rotary wing aircraft. It also assumes that the present method of operation is subject to change, depending upon the requirements of the petroleum industry, and the scale and the timing of exploration and production activities.

Presently these requirements are difficult to predict, being a reflection of uncertainties relating to:

- o national and international economic and marketing scenarios;
- o the imperfect understanding of the production capability of most of the offshore areas under consideration;
- o the precise location of future producing fields relative to potential onshore supply bases;
- o a large number of unresolved socio-economic policy issues,

As a result a clear understanding of the nature and level of future demand on the transportation system was not possible. In order to test the influence of the assumptions on the results, a range of variables were selected as a basis for carrying out a risk analysis. This analysis primarily involved calculating the relationship between the break even traffic levels and assumed variations in the magnitude of selected variables.

Another factor considered in the definition of the basic operating system was the vastly different effective payload/range capability of the

aviation systems being evaluated. Some of these systems were perceived as likely being cost-effective at the lower end of the scale of service and demand levels, while others were seen as being more efficient at the higher end of the demand/service level scale. The evaluation of the selected systems options involved two steps:

Step 1: the determining of the demand and service levels, or "break points", beyond which every alternative being evaluated was more effective than the base case system.

Step 2: the comparison of the traffic level at the break point against existing demand forecasts to assess the likelihood of there being adequate traffic to justify implementation of the system within the time-frame of the study.

In order that the evaluation be achieved systematically the base case requirements and costs were established in terms of pre-selected units of demand. These units could then be aggregated to provide basic costs for any total system demand or operating level of service for comparison with costs developed for the equivalent operating scenarios for each of the alternative systems being evaluated.

7.2 Base Case Independent Variables

Because of the disadvantages of defining the representative base case as single operating scenario, the base case for each geographic zone was defined in terms of matrix of variables bounded by a finite range of values for each of the following independent variables:

- o physical system
- o level of service
- o operating cost

The system variables include:

- o platform or rig size, defined in terms of based employment,
- o the number of platforms or rigs in the system,
- o the number and location of land-based supply centres,
- o estimates of traffic distribution factors between alternative land-side bases to reflect possible natural demand in the context of possible government policies related to industrial development and decentralization,
- o flying destinations between the selected onshore bases and offshore development areas.

The range of platforms or rig sizes was selected to reflect both current situation in Canada, where relatively low standing levels prevail, 75 to 150 persons per offshore facility; and the North Sea experience where operating production platforms can have manning levels in the order of 300 to 350 people.

The level of service variables included:

- o staff rotation period
- o frequency of service
- o shuttle or loop helicopter routing.

The cost variables include:

- o helicopter capacity
- o hourly operating costs
- o flying speed
- o turnaround times on the platform for looped services
- o load factor

7.3 Development of Transportation Cost Equations

Practical offshore transportation service levels are usually based on accepted industry standards and local wage agreements, helicopter operating costs, and aircraft availability. This study approaches the problem from a more theoretical perspective in that it attempts to establish the manner in which transportation costs for a variety of transportation systems are affected by variations in service level for different levels of offshore employment at each of the three offshore locations.

The methodology used was a deterministic one whereby unit transportation costs (expressed in terms of dollars/annum/platform employee) were calculated for a pre-determined number of practical cases, at fixed increments of demand, and for a number of pre-selected service levels. This methodology did not directly allow for the optimization of equipment utilization.

Because of the limited availability of suitable helicopter types, the methodology often resulted in a significant mismatch between seat availability and demand. The calculated helicopter operating costs therefore were found in some cases to be highly sensitive to small changes in demand. For example, 44 passengers can be carried in a single Boeing Chinook helicopter and on some routes this results in the most favorable unit passenger transportation cost. However, adding one passenger to the demand would result in a disproportionate cost increase because the methodology requires that either two Boeing Chinook helicopters at double the cost be introduced, or, that three smaller helicopters, at an even greater operating cost be assumed. In practice this situation would be corrected by slightly adjusting either the demand or the level of service to be provided.

In order to partly compensate for the lack of system optimization in the methodology, average cost equations were developed for each route.

The number of seats to be provided on a typical day was selected as the independent variable, and helicopter operating costs was selected as the dependant variable.

The likely number of seats required was related to units of demand generated by groups of offshore platforms (ranging from 1 to 3) in number, with employment levels ranging from 75 to 300 persons. Daily seat requirements were found to range from approximately 4 to 100 depending upon the service frequency assumed for each traffic demand level.

For the purposes of developing the average cost equations, seat requirements were assumed to increase in 4 seat increments over the demand range. The cost of providing the required seats was calculated separately for each demand level by selecting the helicopter or helicopter combination which provided the necessary seats at the lowest cost. The helicopter capacity and cost information for all routes and production areas under consideration are summarized in Section 10 Evaluation of Alternative Aviation Systems.

7.4 Base Case Observations

Based on the costing methodology, the most expensive service, within the three geographical areas would be a daily, direct shuttle, serving the smallest platform (75 based employees) on a one week rotation. This service would cost between \$353 to \$656 per person trip for the Scotian Shelf (Halifax Base), \$473 for the Hibernia System, and \$219 (Hopedale) to \$341 (Hopedale/Cartwright) within the Labrador Sea System.

The cheapest would involve the transfer of 300 passengers from a single platform every three weeks, on alternate days. Such a service would cost approximately \$271 per person trip at the Scotian Shelf, \$367 for Hibernia, and \$166 to \$236 for the Labrador Sea (Hopedale and Hopedale/Cartwright).

At all three geographical areas there would be cost savings associated with a loop service serving 2 rigs. Only a marginal reduction in cost, (if any) would be achieved with a loop service including a third rig. This dropping off in efficiency results from the fact that the cost saving from improved load factors are offset by the incremental cost increases associated with increased equipment use and flying time involved in travelling between successive platforms. Within the Scotian Shelf, a loop service to three rigs is more cost effective at lower passenger traffic levels, while at higher volumes, a two rig shuttle is less costly. Similar trends are not as evident within other types of service or systems.

Of significant interest are the cost savings associated with two and three week staff shift rotations over weekly rotations which are summarized in Table 26.

LOCATION	% ANNUAL COST SAVINGS PER BASED EMPLOYEE*		COMMENT
	2 WEEK ROTATION	3 WEEK ROTATION	
Scotian Shelf	30.7%	42.9%	* when compared to a shuttle service per 1 week rotation
Hibernia Shelf	31.7%	42.1%	
Labrador Sea			
Hopedale	29.8%	39.9%	
Cartwright	30.2%	42.7%	

Cost Comparison Associated with Shift Rotation

Table 26

* 75 person based platforms, daily service.

On average transportation costs for crew rotations on a three week cycle are approximately 20% lower than those for bi-weekly rotations but these savings are highly sensitive to platform size, decreasing as the platforms increase in size.

Cost variations are not as significant when considering platform size, although for a fixed service levels costs decrease as platform size increases as this results in improved load factors. This advantage becomes negligible for platforms sizes over 200 based employees.

Variations in cost associated with traffic split, were also of interest in order to establish whether it would be more effective to shuttle from one mainland supply base or a number of centres. In the case of the Scotian Shelf system, the cost of transferring passengers to and from Halifax for a rig with an employment base of 150 person is \$286 per one way trip, for a two week rotation and \$324 for a three week rotation. A similar service, originating from two shore bases with 75% of the traffic originating at Halifax and 25% of the traffic originating at Sydney costs \$323 per trip for a two week rotation and \$384 per trip for a three week rotation, an increase of 12% and 18% respectively. This occurs despite Sydney's proximity to the offshore location. In examining trip costs assuming multiple centres of origin, namely, Halifax/Sydney/Yarmouth, a similar service would cost \$490 and \$559 per trip, respectively. The cost penalty resulting from this latter split results partly from less effective utilization of aircraft, reduced load factor and partly from the greater flying distance from Yarmouth.

In the Labrador Sea system, a traffic split of 75% Hopedale/25% Cartwright compared to all traffic being based at Hopedale results in a cost increase of 32% to 75% assuming two week rotation over the range of service levels examined and 42% to 86% assuming a three week rotation (75 employee base platform, daily service).

Splitting traffic between a number of land bases, appears to increase trip costs in all cases studied, assuming common levels of service. The final selection of a base for shuttle services within the Labrador Sea system should be assessed in the context of the overall regional transportation system. Although trip costs associated with a base at Cartwright appear to be higher than those for Hopedale, Cartwright may

be a more desirable choice of base due to its proximity to St. John's, the regional base of the involved petroleum companies.

Alternate day service results in a significant cost saving over daily or weekday service, and allows flexibility to make up trips lost due to weather related delays. Within the Scotian Shelf, a direct shuttle on alternate days is 23% less expensive than the daily shuttle at the lower end of range of assumed traffic levels and 9% less expensive at the higher end; it is 10% less costly than the weekday service at the lower demand levels. For the Hibernia zone, the costs for an alternate day service are 9-22% less than for a daily shuttle and 3-6% less than, for a weekday service. At Labrador Sea (Hopedale) the comparable cost savings are 10% and 25% respectively.

For the comparative systems evaluations carried out in this study, the range in base case variables was assumed to be as follows:

- o rig size - 150 to 200 employees
- o shift rotations - 2 or 3 weeks
- o minimum trip frequency - alternate days
- o service - direct shuttle for to 2 rigs in one loop.

8.0 FIXED WING AIRCRAFT

8.1 Aircraft Availability

On the basis of three key selection factors:

- o operating cost
- o short field performance, and
- o passenger capacity

the de Havilland Dash-7 was selected as the primary aircraft in the fixed wing aircraft system scenarios for offshore support. On the basis of these selection factors the viability of this aircraft has been proven over many years of commercial commuter operations, and has satisfactorily demonstrated the practicability of short take off and landing (STOL) operations.

Other aircraft having STOL capability, the Twin Otter, Dash 8 and Buffalo were considered but ultimately rejected for the following reasons. The STOL version of the Twin Otter has a seating capacity of only 10-11 passengers and as a result was judged to have inadequate capacity in the context of this project. The Dash-7, by comparison, has a seating capacity of 50. The Dash 8 requires approximately 50% greater field length for takeoff than does the Dash-7, which is a very significant drawback in an offshore STOLport application. The Buffalo is presently certified as a military transporter and may not be certified for civilian operation.

The Dash-7 is capable of serving all routes in the proposed offshore system without payload penalty except for the marginal Gander/Hibernia route (590 nm round trip), which entails a payload reduction of 5 passengers. Taking into consideration the effects of en-route winds at all three offshore areas, approximately 12.5% more fuel is required for flights experiencing 20 knot headwinds, (conversely 20 knot tailwinds would result in an approximate saving of 9.4% fuel consumption).

Currently, de Havilland is considering redesigning the Dash-7 to a 70 or 80 passenger seating configuration. Also under consideration are modifications involving the installation of a new model of engine that could add 50 mph to the aircraft's cruising speed. These changes, however, will not be favourable in the context of this study as they will result in an increased take off runway requirement now anticipated to be 912m.

Operating characteristics of the Dash-7 are itemized as Table 27 and detailed in the subsequent sections of this chapter.

DESCRIPTION	VALUE	COMMENT
Seating Capacity	50 people	At 81 cm Pitch, Maximum 54 Seats
Maximum Cruise Altitude	7600 m	
Take Off Weight (Max.)	20,000 kg	
Landing Weight (Max.)	19,091 kg	
Fuel Capacity	2,545 kg	
Maximum Cruise Speed	231 Knots	At 2432 m ASL, 227 Knots 4560 m ASL
Range	500 nm	50 passengers at 100 kg, IFR reserves 100 nm, Diversion, + 45 mins. fuel LRC
Maximum Range	1,100 nm	As above except payload 35 passengers at 100 kg each
Take Off Field Length	687 m	FAR 25, 25° flaps, zero wind, ISA - Sea Level, Payload 20,000 kg
Landing Field Length	593 m	STOL, 45° flaps, screen length 10.6m, speed $1.3V_{SO}$, dry based landing surface zero wind, field length factor 1/0.6, weight 19,091 kg.
Crosswind Capability	15 knots	Under IFR Cat II conditions (In excess of 20 knots, VFR conditions)

Dash-7 Capability

Table 27

8.2 Aircraft Certification Characteristics²⁰

The Dash-7 has been certified in the civilian transport category in compliance with Federal Aviation Regulations, F.A.R. Part 25 (up to and including amendment 35). The aircraft is therefore eligible for the following categories of operations:

1. Day and Night Visual Flight Rules (VFR)
2. Instrument Flight Rules (IFR)
3. Icing Conditions.

Maximum Structural Weight Limits

Ramp Weight	- 20045 kg (44,100 lbs)
Take-Off Weight	- 20000 kg (44,000 lbs)
Landing Weight	- 19090 kg (42,000 lbs)
Zero Fuel Weight	- 17727 kg (39,000 lbs)

Operating Altitudes

Critical operating altitudes are as follows:

Maximum Operating Altitude - 7600m

Maximum Operating Altitude With Passengers - 6200m

Operating Speeds

The following maximums apply to specific altitude ranges:

Altitude Range

Operating Speed

Sea Level to 2280m
2280 m to Maximum
Operating Altitude

231 Knots
(Decrease speed by 4 kts for each
3040m above 2280m)

²⁰ The de Havilland Aircraft of Canada Ltd. Dash-7 Flight Manual
PSM 1.71 A-1A, Downsview, February, 1979.

Speeds (EAS's) at selected flap settings are as follows:

Flaps extended -

15° Flap setting 147 kts
25° Flap setting 120 kts
45° Flap setting 110 kts
(landings).

Minimum Control Speeds

Aircraft Airborne (Vmca)

Flaps 15° 69 kts I.A.S.
Flaps 25° 65 kts I.A.S.

Aircraft on Ground (Vmcc)

Flaps 15° 68 kts I.A.S.
Flaps 25° 58 kts I.A.S.

Cross Wind Capability

Adequate control during landing has been demonstrated in cross winds up to the components given below, as measured at a height of 10 metres above the landing surface. These are maximum 90° components experienced during cross wind trials on dry runways. They are not considered as limiting.

- a. All engines operating - 22 kts
- b. One engine inoperable or outboard spoilers inoperable - 18 kts.
- c. Under IFR Conditions for Category II Landings - 15 kts.

Maximum Tail Wind Components

The following maximum tailwind components at a reported height of 10 metres above the landing surface are allowable.

Take-offs: Flap Settings 15° and 25° - 15 kts

Landings: Flap Setting 45° - 20 kts

Icing

The aircraft is equipped with two types of de-icing systems:

- a. propellor de-icing
- b. airframe de-icing.

The latter system consists of de-icing boots fitted on the leading and trailing edges of the wing and tail surfaces.

8.3 Automatic Landing System Requirements

As discussed, the weather statistics for all three offshore development zones under study, indicate a high incidence of weather below IFR Category II (landing limits: 30m ceiling, 400m horizontal operating visibility). Significant economic benefits might be achieved if Category III operations at the offshore airports were possible. It is important to note that the ceiling minima are measured from the landing surface, so that in the case of the floating airports under consideration, the ceiling minima for Category II operations rises to approximately 45m to 61m ASL, thereby further reducing airport availability from that estimated from offshore weather data.

Automatic landings under Category III conditions are currently permitted at some land based airports outside Canada. Such operations remain uncertified in Canada, partly because there has not been a pressing demand considering the generally low incidence of Category III weather conditions.

In a technological sense, fully automatic landing systems for fixed wing aircraft should be considered "state of the art", with wider utilization being limited more by economic considerations than safety concerns.

The autopilot in the Dash-7, (Sperry SPZ-700) is approved for Category II operations, but must be disengaged for landings. Since it is an analogue system, it lacks fully automatic landing capability because it has no back-up system in the automatic mode.

Although de Havilland Canada has considered upgrading the autopilot in the Dash-7, this possibility is not being actively considered at the present time. However, the company has not ruled out the possibility of equipping the aircraft with a fully automatic dual channel digital landing system, should it prove economic to do so.

In the context of the current study, offshore Category III operations utilizing the Dash-7 aircraft should not be discounted on technical grounds.

RNAV System

En route IFR operations are limited to a distance of 130 nm or less (40 nm or less at 5472m and below) from a VOR/DME or VORTAC facility.

8.4 Vertical Closing Speed on Landing

The vertical closing velocity of the Dash-7 during normal landings ranges between 1 and 2 metres per second. The aircraft's undercarriage is designed to withstand forces having a vertical closing velocity of 3m/sec. In order to stay within a limit of 3m/sec., landings on the STOLport must be carried out during periods when the upward motion of the structure, due to the combined motions of pitch and heave, results in a vertical velocity of less than 1.2m per second at the touchdown point. The touch down point for the aircraft would be approximately 100m from the landing threshold, assuming a 10.6m screen height at the threshold and a 6 degree glide slope. Visual perception and judgemental assessment of the vertical velocity of the STOLport will be difficult. Consideration may have to be given to the development of a

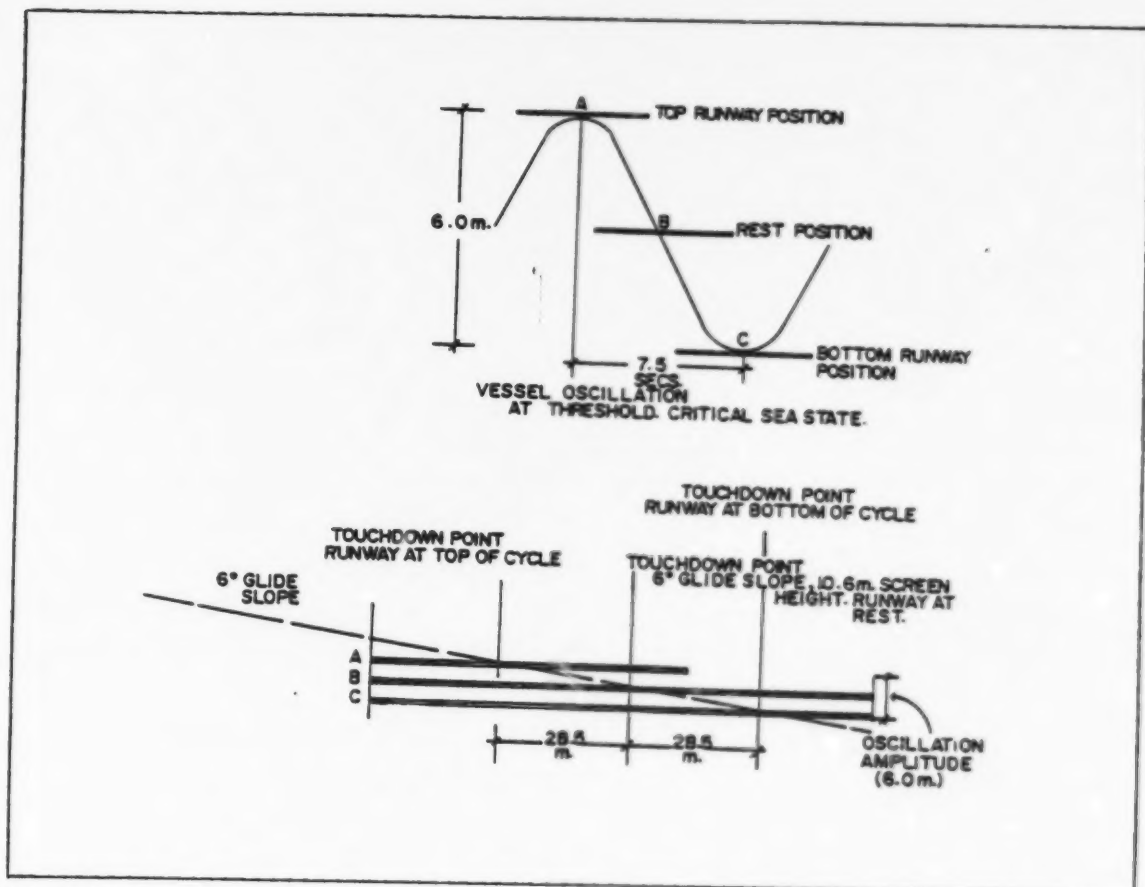
detection/warning system for advising pilots of excessive vertical closing velocities.

During the heave/pitch cycle, the floating STOLport will rise and fall relative to the position of the aircraft on final approach. During the rising motion, the strength of the undercarriage is the critical factor that governs allowable vertical closing velocities. The vertical rising velocity of the structure and the sink rate of the aircraft are additive. Requirements could be demonstrated through mathematical simulation models or a real time simulator.

During the falling cycle of the vessel, the net closing velocity is reduced to the differential sink rates of the aircraft and the vessel. In the worst condition, the sink rate of the structure could exceed the vertical closing velocity of the landing aircraft. Depending upon the skill of the pilot, the tendency will be for the aircraft to land long, thereby decreasing the landing runway margin of safety. Requirements could be demonstrated through mathematical simulation models or a real time simulator.

Preliminary performance estimates for the hull indicate that under critical wave conditions, the total vertical movement of the floating runway threshold from a trough to crest cycle will be 6m and that this movement will occur over a time period of 7.5 seconds. The calculated point of touchdown, assuming a 6° glide slope and a 10.6m screen height, will vary laterally by approximately plus or minus 28.5m from the theoretical point of touchdown under calm conditions. This is illustrated in the following sketch.

Because of visual perception problems noted previously, some detection device may be required to warn pilots of a potential negative vertical velocity problem. It may also be necessary to develop equipment which



Touchdown Points Achieved Relative to Wave Stage

Figure 19

would either audibly or visually warn the pilot of his proximity to the safe touch down point, possibly by adapting carrier based equipment.

8.5 Runway Requirements

Terminology

The terminology relevant to this section is defined below. The definitions are abridged from the de Havilland Dash-7 Flight Manual DSM-1-71A-1A.

- V1 - (Critical engine failure recognition speed) - Speed at which, due to engine failure or other causes, the pilot may elect either to stop the aircraft or to continue take-off.
- VR - (Rotation Speed) - Speed at which aircraft rotation is initiated during take-off to attain the required V2 climb speed at or before a height of 10.6m above the take-off surface.
- V2 - (Take-Off Safety Speed) - The climb speed to be attained at or before a height of 10.6m above the take-off surface during a continued take-off following an engine failure.
- V35 - Take-off speed to be attained at or before a height of 10.6m feet above the take-off surface during a continued take-off with all engines operating normally.
- TOD (Take-Off Distance) - The take-off distance is the longer of the following:
- The distance from the start of the take-off roll to the point where the aircraft attains a height of 10.6m above the take-off surface, with critical engine failure at V.
 - 115 percent of the distance from the start of take-off roll to the point at which the aircraft attains a height of 10.6m above the take-off surface with all engines operating normally.
- ASD (Accelerate Stop Distance) - The accelerate stop distance is the sum of the following:
- The distance required to accelerate the aircraft from a standing start to the speed V1.
 - Assuming a critical engine failure at V1, the distance required to bring the engine to a full stop from the point at which V1 (speed is attained).

Balanced Field Length - This holds when the take-off distance equals or exceeds the accelerate stop distance.

Take-Off Run - Refers to the case where the take-off distance available (TODA) includes a clearway (unbalanced field length). The take-off run is the longer of the following:

- The distance from the start of take-off roll to the mid point between lift off and the point at which the aircraft attains a height of 10.6m above the take-off surface, with critical engine failure at V1.

- b. 115 percent of the distance from the start of take-off roll to the mid point between lift off and the point at which the aircraft attains a height of 10.6m above the take-off surface, with all engines operating normally.

Clearway - The area beyond the edge of the take-off surface, being a width of or 152m minimum, centred on the extended centreline of the take-off runway under the control of the airport authority. The clearway plane extends from the end of the runway at an upward slope not exceeding 2.5%, above which no object or terrain protrudes.

Runway Length Requirements

The runway length calculation for the Offshore Airports are based on the methodology outlined in the de Havilland Canada Dash-7 Flight Manual PSM 1-71A-1A Section 4 - Performance Data. The methodology is in accordance with FAR 25 and is Department of Transport (U.S.) approved.²¹

Take-Off Runway Requirements

Of the three offshore development areas under consideration, the most critical location from the point of view of aircraft performance related to weather conditions and stage lengths is the Hibernia zone.

The representative airport reference temperature for the offshore is taken as the upper 95 the percentile of the temperatures prevailing during the hottest month (20°C, August, equivalent to ISA + 5°C).

An examination of wind conditions at the selected sites indicates that if the floating airport was turned in such a way that landings were

²¹ Department of Transportation, Federal Aviation Administration Advisory Circular No. 150/5300-8 Planning and Design Criteria for Metropolitan STOLports. Washington November, 1970.

always into the wind, a head wind of 5 knots or greater would be present, on average, 95 percent of the time.

The allowable payloads for the Dash-7, for a range of take-off runway lengths were calculated in accordance with FAR 25 assuming the following factors:

Altitude - Sea Level
Temperature - ISA + 5°C
Headwinds - 5 knots
Screen Height - 10.6m
Flap Setting - 45°
Runway Slope - 0%
Runway Conditions - Hard and Dry.

The runway length to payload relationship for the Dash-7 results indicate that the 600 m. runway length primarily calculated by Seaforth Maritime is adequate to allow take-offs at maximum payload, under most operating conditions, at all three areas under consideration.

Landing Runway Requirements

The landing field length required in accordance with procedures as specified in FAR 25, are based on the following conditions:

- o All engines operating or with one engine inoperative.
- o Screen Height 10.6m
- o Wing Flaps 45°
- o Approach Speed [42000 lbs (19090 kg) landing weight] - 81 kts.
- o Runway - Dry on a hard surface
- o Retardation - maximum main wheel anti skid braking, ground and roll spoilers extended, 3 propellers at DISC
- o Wind Conditions - still air
- o Field Length Factor - 0.6 - 5 knots head winds

The calculations indicate the following landing runway length requirements:

- o Still air - 593 metres
- o 5 kt head winds - 562 metres

At dry conditions brake energy absorption is not limiting, so that the standard turn around time of 5 minutes minimum would apply.

8.6 Aircraft Arrestment Systems

Background

The case for investigating the need for aircraft restraining devices on elevated STOL runways tends to be based on U.S. naval aircraft carrier experience. In naval operations, landing aircraft have missed or left the runway in almost every conceivable manner despite sophisticated flight guidance and restraining systems. As a result of this adverse experience, there has been considerable research and development work carried out on improved mechanical systems offering either lateral or longitudinal restraint, or in some cases both.

Experience with restraining devices on aircraft carriers, has resulted in a number of investigations into the need for, and the likely effectiveness of similar equipment on elevated STOL runways, which by their nature do not have the protective graded areas found at the sides and ends of conventional ground level runways.²²

²² Haviland, J.K., A Preliminary Study of Container Concepts for Aircraft Landing on Elevated STOLports. Report #AEEP 4068-101-71U Division of Aerospace Engineering and Engineering Physics. Research Laboratories for the Engineering Sciences, U. of Virginia, Charlottesville, October, 1971.

Lucero, F.N., The Arresting Cable Pop-Up Device. AFFTC-TR-61-17 United States Air Force - Edwards Airforce Base, April, 1961.

Zagarella, A. et al, Arresting Gear Tests for Elevated Short Take-Off and Landing Ports (STOL) Dept.of Defense Lakehurst, Nov,/72

With floating STOLports, which are subject to heaving, rolling and pitching due to wave action, restraining devices are possibly more necessary than with elevated fixed runways. A further potential problem with floating STOLports vis a vis land-based STOLports is the difficulty, in the case of the former, to achieve effective rescue operations particularly during adverse conditions of heavy seas, freezing air and water temperatures and poor visibility.

Assessment of Need

In assessing the need for restraining devices, two fundamental questions factors were considered:

- a. is the proposed runway long enough to safely accommodate aircraft landings with a reasonable factor of safety to allow for possible equipment malfunction, pilot error or loss of runway surface friction?
- b. is the proposed runway wide enough to laterally contain the aircraft under the adverse eventualities referred to under paragraph (a)?

The primary causes of loss of runway friction are water and/or ice on the runway surface. Aircraft performance on ice, particularly near the triple point, is completely unpredictable; therefore, operations should not be contemplated from icy runways.

Wet runway conditions at offshore locations will be a common occurrence, but assuming proper runway drainage, to prevent hydroplaning, the effect of water on aircraft stopping distance is predictable. It is understood that special high friction runway surfaces have been developed for U.S. Navy use to compensate for loss of friction due to wetness. The availability and performances of such surfaces is being investigated. In this connection, it should be noted that open grid runway surfaces are not recommended, as during landings they bleed off

air thereby destroying the ground effect which normally supports the aircraft just prior to touchdown.

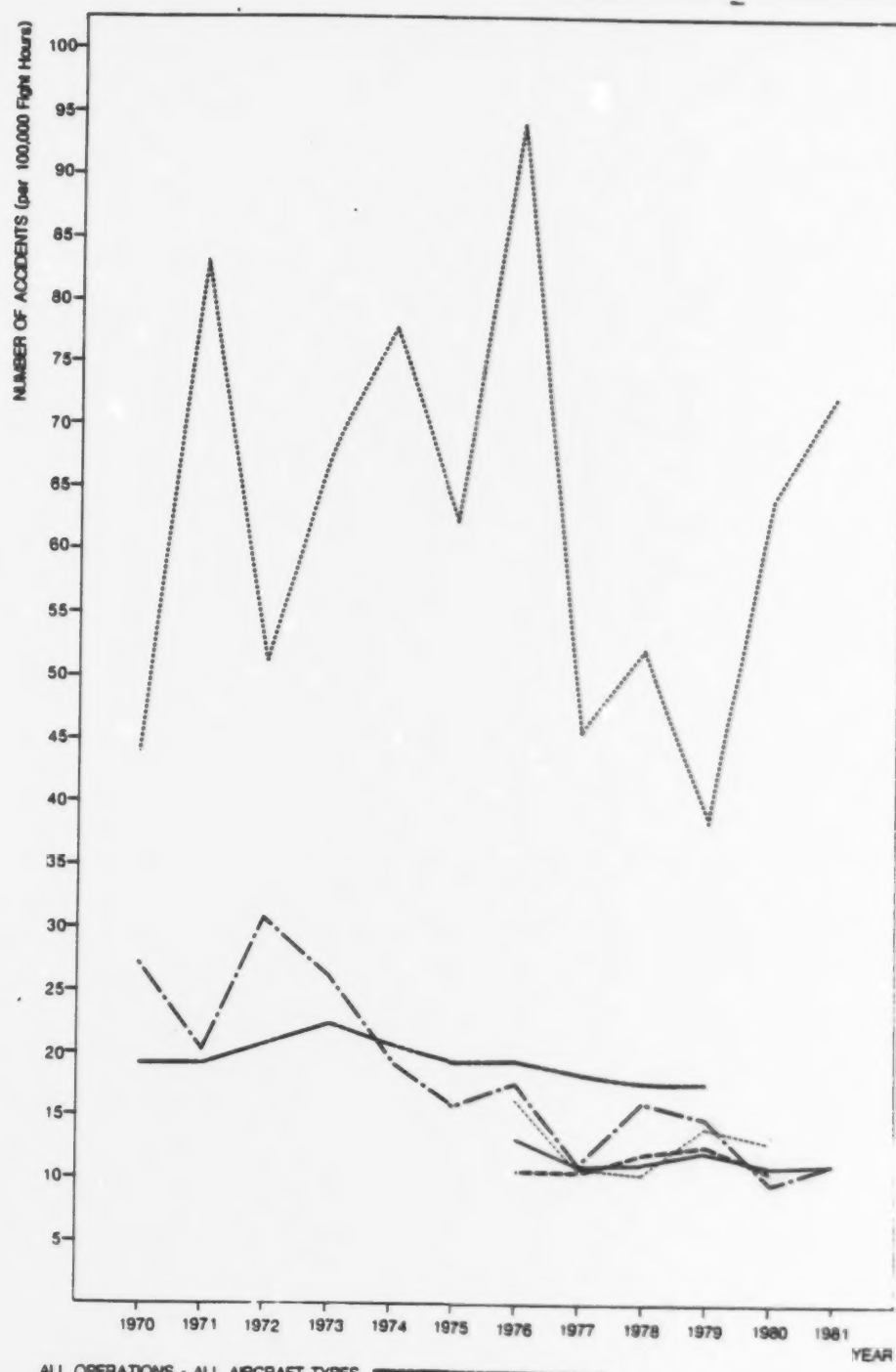
Statistics relating to land accidents on runways are shown in Table 28. Their relevance to STOL operations is questionable due to the relatively small number of such aircraft in service during the survey period. More relevant statistics are those from STOL operations during the Transport Canada sponsored Air Transit Demonstration Project. Over a six month period, which included winter operations, one thousand landings were performed with a de Havilland Twin Otter, without serious incident.

	TYPE OF OVERRUN		TOTAL
	SIDE	END	
<u>CAUSE</u>			
Controls	22	4	26
Wheels/Tires	8	7	17
Trim/cg	1	4	5
Engine Failure	4	4	8
Other/Not Reported	3	8	11
<u>OCCURRENCE</u>			
Before V ₁	9	2	11
At or near V ₁	2	4	6
After V ₁	5	16	21
Not Reported	22	5	27
<u>CASUALTIES</u>			
Fatal	4	9	13
Serious	7	5	12
Minor/None	27	13	40
TOTAL	38	27	65

Rejected Takeoff Overrun Accidents²³

Table 28

²³ Newman, R.L., Airport Related Accidents-Landings, CPS 76-5, Transport Canada, Ottawa, 1976.



ALL OPERATIONS - ALL AIRCRAFT TYPES
 COMMERCIAL OPERATIONS-ALL AIRCRAFT TYPES
 CHARTER/CONTRACT-FIXED WING
 CHARTER/CONTRACT-ROTARY WING
 SPECIAL PURPOSE-FIXED WING
 SPECIAL PURPOSE-ROTARY WING

TRANSPORT CANADA

AIRCRAFT ACCIDENT RATES (canadian)

figure 20

Short of actual operating experience, it is unlikely that the argument as to the need for longitudinal restraint can be resolved. Since it is considerably cheaper to install a restraining device than to lengthen the runway, it is recommended that the minimum runway length be assumed for study purposes and that a restraining device be incorporated in the design pending resolution of this issue.

The determination of runway width requirements is equally difficult. Accepted design standards for elevated STOLport runways require a 92m runway width. Because the floating STOLport landing surface is dynamic, an argument can be made in support of a runway width exceeding that recommended for fixed runways. Two contrary arguments must be considered. First a major factor affecting the lateral movement of aircraft on landing is the crosswind component. The floating STOLport will be aligned with the wind to the extent permitted by sea conditions, therefore, crosswind components in excess of 15 knots during Category II conditions will, on average be acceptable. Second the majority of the landings will be made into headwinds exceeding 5 knots, thereby reducing the landing speed of the aircraft relative to the landing surface.

During the initial phases of this study, consideration was given to the possibility of reducing the width of the landing surface to 60m due to the potential for reducing the crosswind component through vessel positioning. In the event, vessel dynamics indicated that a 92m beam was desirable to achieve vessel stability thus eliminating further consideration of narrower runways.

8.6.1 Longitudinal Restraint Systems

Longitudinal restraint systems fall into two categories:

- a. Active systems which arrest all landings during the periods of activation.

- b. Passive systems which require activation by the pilot, or by a controller in liaison with the pilot.

There appears to be very little support with the civilian aviation community for an active restraining system on STOL runways designed to meet FAR 25 requirements. In the case of the Dash-7 aircraft, it is unlikely that its structure as presently designed could, long withstand the heavy stresses associated with restraining systems currently available.

A passive system, used as the safety device of last resort would be more favourably received. The decision as to when to use the restraining system or to attempt take off would be left to the pilot who would activate both the aircraft based and vessel based components of the system from the cockpit.

8.6.2 Lateral Restraint Systems

Presently, a suitable lateral restraint device is not available for this type of operation. The most that can be expected of the state-of-the-art solutions is to prevent an out-of-control aircraft from going over the side of the runway so that rescue operations would be possible. A simple energy absorbing guard rail system which would restrain the aircraft at fuselage height appears to be the most suitable. As yet, such a guard rail system remains to be developed.

Runout Situations

The estimated "runout" distances for non-emergency situations are:

Non-emergency end or lateral overrun - 152-244m runout

Emergency lateral overrun - 18-30m runout

Emergency end overrun - 40-67m runout

Deceleration Tolerance Levels - Passengers

FAA research has recorded the following comfort tolerance levels for abrupt deceleration situations:

Non-emergency	- 0.4 to 0.67 g.'s
Emergency	- 1 to 2.5 g.'s with minimal discomfort
Military Emergency	- to 2.9 g.'s average

8.6.3 Arrestment Concepts Suitable for Use on the STOLport²⁴

Hooks and Wires

This standard concept primarily involves the deployment of a reinforced, retractable aircraft mounted hook, sensing equipment, arrestment engines and transverse runway wire(s), which engage the landing aircraft, causing a pulling action. This method is re-usable, reliable and popular, however, the disadvantages to its use lie in its limited success with aircraft experiencing tail-high attitudes and overruns of 10°+ angle deviations. The equipment must be capable of being adjusted for aircraft weight and speeds. It does not guarantee aircraft capture and could pose a problem, as an obstruction, to aircraft attempting a missed approach go around. A comparison of concept effectiveness and relative costs is presented in Table 29.

Shielded Arresting Gear

This concept is similar to the previous system, except that the equipment and wires are embedded and subject to a longer response time. It should, however, pose less of an obstacle to recircling aircraft.

²⁴ Transport Canada, A Survey of Airplane Arrestment Techniques, CPS-76-1, Transport Canada, Ottawa, 1976.

Deployment of Nylon Nets

This system is adequate for aircraft capture but could also be an obstruction to aircraft attempting a missed approach go around. These nets require more de-icing and snow removal than the other two concepts described.

Additional Concepts

Additional systems include:

- o strut engagement
- o gravel beds
- o barricades
- o deforming barrier (e.g. shrubs)
- o sliding arresting engines
- o ditches
- o banked slopes.

These systems were rejected because of their potential for damage to aircraft or impracticability in the context of a floating facility.

All three restraining systems identified are reusable, with non-emergency use an option for consideration. Runway lengths, fuel consumption and operating times could theoretically be reduced because of this option. Industry representatives, however, do not promote use of arrestors, since the DASH-7 is designed to land in short distances, and the STOLport vessel design ensures headwind approach, assisting in the rapid deceleration of the aircraft, FAR 25 runway design criteria were used in the STOLport design requirements providing for substantial runway manoeuvring.

Accident information for rotary wing and fixed wing aircraft is compared on Figure 20.

RATING FACTORS	HOOK & WIRE	SHIELDED WIRES	NETS	OTHERS COMBINED
Response/Effectiveness	1	3	2	4
Cost of Installation in Aircraft	4	3	2*	2*
Other Installation Costs	1	3	4	2
Maintenance Costs	1	3	4	2
Snow Removal Costs	2*	2*	4	3
Damage to Aircraft	1	2	3	4
Average Rank	1.6	2.6	3.1	2.8

Rank Order of Arrester Effectiveness

Table 29

* Tie rating
1 = Best Rating

8.7 Airship

A further option for offshore air transport is the Canadian made Airship Industries' Skyship 500. The blimp features a 50.1m long by 13.9m diameter helium filled envelope with a capacity for 20 passengers in its gondola. Its range of operation may be varied from 500 nm at a maximum cruise speed of 60 knots, to nearly 2,000 nm at a lower cruising speed of 30 knots.

This option, while noteworthy, is judged to be inadequate for the purposes of this study due to its slower cruising speeds relative to other aircraft modes and limited passenger capacity. Improvements for the airship are being researched presently, which may strengthen its chances as a viable cargo transport vessel.

8.8 Operating Costs for Aircraft Operations

8.8.1 Basis of Comparison with Rotary Wing Aircraft

It is intended that rotary wing and fixed wing aircraft operating costs be compared on an equal basis to the fullest extent possible. The rotary wing aircraft costs have been developed on the basis of current practice on the Atlantic Coast and are considered under three headings:

Capital Costs

- o Aircraft
- o Spares

Fixed Charges (Monthly)

- o Personnel
- o Depreciation
- o Insurance
- o Interest Charges
- o Management
- o Profit

Hourly Charges

- o Fuel
- o Maintenance
- o Oil

The cost format used for rotary wing operations differs marginally from that commonly used for estimating fixed wing aircraft costs. However, is used here for both, for sake of conformity.

In addition there are a number of minor charges that apply including:

- o Hangar Fees
- o Overnighting Fees
- o Landing Fees

In the case of the rotary wing aircraft, there is already a body of in-service experience upon which to base cost estimates. In the case of the Dash-7, in-service experience is primarily in the commuter field and therefore some adjustments to currently experienced operating costs are necessary to reflect offshore factors.

8.8.2 Costing Assumptions Fixed Charges

Annual Operating Hours

The fixed, monthly charges for helicopter operations assume 1,000 operating block hours annually per aircraft. This is accepted as being reasonable within the helicopter charter industry. Fixed wing commuter operators on the other hand commonly achieve between 2,000 and 3,000 block hours annually per aircraft.

$$\text{Dash-7 Block Time (min.)} = 7 + \frac{\text{Distance (nautical miles)} \times 60}{205}$$

* 7 minutes ground and air manoeuvre allowance.

Block times at maximum cruise speeds are 10% less than at optimal cruise.

Since the Dash-7 aircraft has a greater flying speed and longer range than conventional helicopters, it is more versatile and it would be reasonable to expect 2,500 block hours of operation annually, assuming

a combined onshore and offshore operations. This dual role would allow the aircraft to link a number of land based airports to the offshore facility. Since commuter demand tends to peak in the early morning and the early evening, and since favourable weather conditions for offshore applications generally occur during the late morning and early afternoon periods, the two operations should be compatible.

Depreciation

The rotary wing aircraft depreciation charges are based on industry practice of 10% straight line depreciation to 15% of the residual value of capital cost (equivalent to 8.5%) annually.

For commuter operations, fixed wing aircraft depreciation charges are generally 8.5% per year straight line to 15% of residual value (equivalent to 7.2%) annually. It is being assumed for study purposes that the aircraft would have a dual role, partly traditional and partly operating as an offshore shuttle service, so the standard 7.2% annual equivalent depreciation rate is employed.

Insurance Rates

Insurance rates currently prevailing for rotary wing aircraft engaged in offshore operations are 6% of the aircraft capital cost. There are no equivalent rates for Dash-7 operations. Typical insurance rates in the commuter industry are:

Hull Insurance	-	1.0% of capital cost
Other	-	.3%
War Risk	-	0.0375%
Liability	-	.12 cents per revenue passenger mile (approximately 0.5% annually assuming 400,000 annual revenue miles per aircraft).

The total insurance cost for a Dash-7 in commuter service would be approximately 1.84% of the capital cost of the aircraft.

For a one year period it is estimated that approximately 30% of the aircraft landings would be at the offshore facility and 70% would be normal landings at regular airports. Assuming that a 6% insurance rate reflects both helicopter operations and the more risky offshore Dash-7 landings, and 1.84% reflects a normal commuter operation, a composite rate of 3.0% would appear to adequately reflect the rates associated with the fixed wing operations. In the absence of actual experience this value was used.

Interest Charges

For rotary wing operations, a debt/equity ratio of 3:1 was assumed. The interest on the long term debt was assumed at 15% (3 per cent real rate of return). Assuming an initial long term debt of 75% of the capital cost, reducing over time resulted in an average interest charge of 7.5% over the life of the aircraft. This interest rate was assumed to apply to fixed wing aircraft.

Management Charges

These charges, which include all overhead items and special charges were estimated at \$300,000 per year for rotary wing aircraft operations. These costs would decrease on a per unit basis as fleet size increased. However, the figure is representative of today's scale of operation and will be assumed to apply equally to fixed wing aircraft operations.

Profit

The profit target for rotary wing aircraft including risk factor, was assumed to be 20% of the sum of all other charges and direct operating

costs (1,000 annual hours per aircraft). This same profit margin is assumed to apply for fixed wing aircraft, but with annual direct operating costs being based on 2,500 operating block hours annually.

Personnel

The cost estimates for rotary wing operations assume 1,000 hours of operations annually, whereas, those for fixed wing aircraft assume 2,500 hours annually. Operating on a 2,500 hour basis would require three complete crews (800 hours annually) costing as follows:

3 Captains at \$35,000	\$ 105,000
3 First Officers at \$22,000	66,000
6 Cabin Attendants at \$15,000	<u>90,000</u>
Sub-Total	\$ 261,000
Payroll etc. at 20%	<u>52,000</u>
Sub-Total	\$ 313,000
Dispatcher/Office	
4 persons at \$20,000 (2 shifts)	<u>80,000</u>
ANNUAL TOTAL	<u><u>\$ 393,000</u></u>

Hourly Charges

These analyses assume an average trip length of 1.0 block hours and 0.9 flying hours.

Maintenance

Based on a labour rate of \$13.75 and annual flight cycles equal to annual flight hours and an overhead burden of 50%.

	Per Flight Hour	Per Flight Cycle
Labour	\$ 27.50	\$ 18.15
Parts/Material	36.00	24.00
Overhaul Reserve	45.00	30.00
Sub-Total	108.50	72.15
Burden	54.25	32.10
TOTAL	\$ 162.75	\$ 108.25
Per Block Hour:*	\$ 145.75	
	108.25	
	<u>\$254.00</u>	

* Assumes 1 cycle and 53 minutes flying time per block hour.

Fuel and Oil

Consumption 53 mins. flying time @ 200 Gallons per hour @ \$1.94 per gallon (per 4.5 litres)	\$ 342.75
Taxi and Manoeuvring - 7 Imperial Gallons @ \$1.94 per gallon (per 4.5 litres)	31.05
Oil (per Block hour)	<u>3.20</u>
	\$ 377.00

8.8.3 Cost Summary

The capital fixed and hourly operating costs for the Dash-7 aircraft are summarized on Table 30.

<u>1. Capital Cost (\$ Canadian)</u>	
o 1983 Aircraft Cost	\$ 8,500,000
o Spares (10%)	<u>850,000</u>
o Total Capital Cost	9,350,000
<u>2. Fixed Charges</u>	
o Depreciation	673,200
o Insurance*	280,500
o Interest*	701,300
o Management and Base Costs*	300,000
o Crew*	393,000
o Profit	<u>650,000</u>
o Total Fixed Charges	2,998,000
<u>3. Hourly Charges</u>	
o Maintenance (\$254)*	635,000
o Fuel and Oil (\$377)*	<u>942,500</u>
o Total Hourly Charges	1,577,500
<u>4. Total Annual</u>	4,565,500
<u>5. Total Hourly (2,500 black hours)</u>	1,825

Summary of Estimated Dash-7 Costs

Table 30

* Included is cost figure for profit estimate.

9.0 OFFSHORE BASE CONCEPTS

9.1 Scope

The transportation system options considered in this study involved two types of offshore airports, either floating structures or artificial islands, accommodating fixed wing and/or rotary wing aircraft operations. The facilities would also provide hangar space, materials storage, accommodation for personnel, ATC/MET/NAVAIDS and a full range of emergency and reserve services. The concepts considered included variations of:

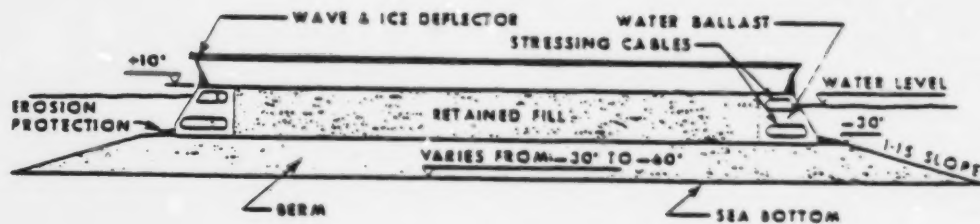
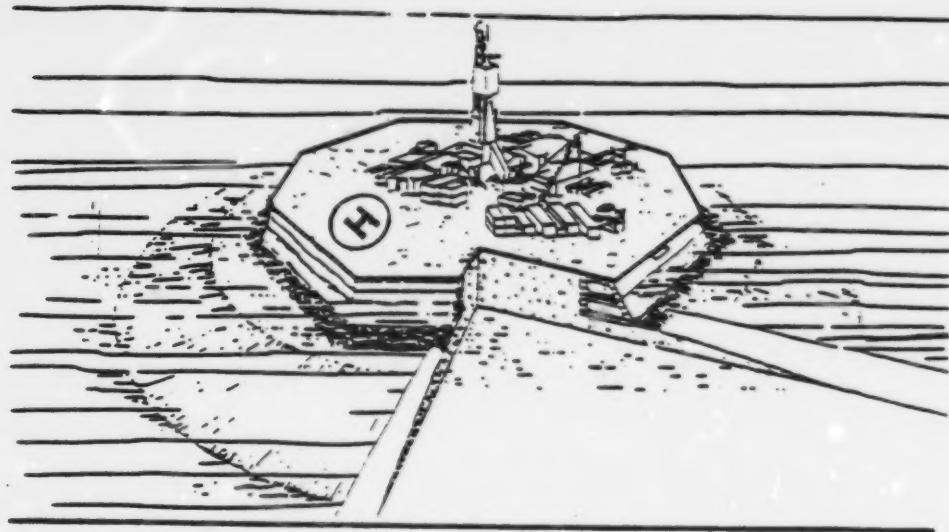
- o artificial island heliports
- o floating STOLport accommodating both STOL aircraft and helicopters.
- o floating heliport, as described in the following sections.

9.2 Artificial Islands

Reinforced concrete bottom-founded or "gravity base" platforms have been built for oil production facilities in the North Sea. These massive structures generally involve drydock construction and are towed to the production site where they are sunk under ballast to the seabed. They have been placed in water depths of up to 150m, and can withstand hostile seastates not unlike those found off of the east coast of Canada.

In Canada, artificial islands using berms have been built as exploratory drilling platforms in the Ice-Infested Beaufort Sea.²⁵ These berms, constructed of local material dredged from the seabed are generally located in shallow waters in the order of 15 metres in depth. In deeper water, progressively greater quantities of fill have been required, which has lead to the development of more economical caisson-retained sand islands as depicted in Figure 21.

²⁵ Imperial Oil Ltd. and Alberty, Pullerits, Dickson and Associates Limited, Design and Construction of A Caisson Retained Island Drilling Platform for the Beaufort Sea. Offshore Technology Conference, 1978.



**ARTIFICIAL ISLAND CONCEPTS:
CAISSON RETAINED ISLAND**

figure 21

9.2.1 Artificial Island-East Coast Context

Several types of artificial islands are currently under consideration, including some designed as a surface-piercing earthfill mound, and a hybrid arrangement of underwater earthfill berm supporting a concrete or structural steel structure. Certain concepts propose adhesion to underwater shoals, use of iceberg deflectors, or accommodation for helidecks, STOL runways and marine landing facilities. These concepts must provide a stable structure, resistant to wave and iceberg attack for yearround operation.

9.2.2 Iceberg Considerations

A major consideration in the design of artificial island based heliports or STOLports is the threat of iceberg collision.

An underwater berm of sufficient size and suitable construction can be used as the first line of defence against large icebergs. The top elevation of the berm is determined by a trade off between the magnitude of impact that the structure can realistically be designed to withstand during an iceberg collision, and the size of armour rock that can be practicably fabricated and placed. The armour is also a method of minimizing the impact of large waves.

Having selected the "design" iceberg, (1×10^6 tonnes) the width of the berm required is determined by the distance necessary to bring a large iceberg to a halt without endangering the structure. Other considerations is the tradeoff between the steepness of the berm side slopes versus the quantity of the fill and armour materials required.

The second line of defence against structural damage from iceberg collision can be a system of arresting cables. For the concepts considered in this study, each arrestor, located on the periphery of the structure would consist of several large diameter wire rope cables

enclosed in sheaths. They would be connected to opposite sides of the base of the structure and looped through the deck. The concepts assumed that a design iceberg of 1×10^6 tonnes making contact with a group of these cables which are deflected would produce a gradually, increasing horizontal force component which would bring the iceberg to rest before it reached the main elements of the structure. The deck and structure would be designed to resist the cable forces.

To cover the possibility of cable failure or non-performance, the structure stem and base would be designed to withstand the full impact of a 1×10^6 tonne iceberg which would have to be brought to rest through the crushing action of the ice itself. The horizontal force to be resisted would be a function of the shape of the leading edge of the iceberg, the crushing strength of the ice, its hydrodynamic mass and drift speed. For the purposes of this study a horizontal force of 25,000 tonnes was assumed to act on the system. The structures would have an adequate factor of safety against overturning and sliding induced by a force of this magnitude.

9.2.3 Heliport Hybrid Alternatives

Two artificial island heliport concepts considered in the study are shown on Figure 22. The structure has a 120m diameter structural steel helideck supported by a single stem and solid base both in reinforced concrete. The structure is founded on an underwater earthfill berm in water depths of 8-100m. The island has estimated quantities of 7 Million m^3 of fill and 90,000 tonnes of armour; the structure totals 105,000 m^3 of concrete and 10,300 tonnes of steel; estimated cost is \$564 Million (Cdn.).

The deck tank provides buoyancy and stability during towing and placing. It is attached to the base through a series of wire, rope, tackle assemblies connected to winches on the deck. No ballast is required during sinking, after which the deck tank is jacked up into

its final position and structural connections are made. Iceberg arrestor cables are then installed.

The deck tank is considered unstable until the wind sections are added ultimately.

A variation of this concept, Alternative 2, provides a square reinforced concrete base of cellular construction, providing a variation in construction and placing techniques as well as implementation costs.

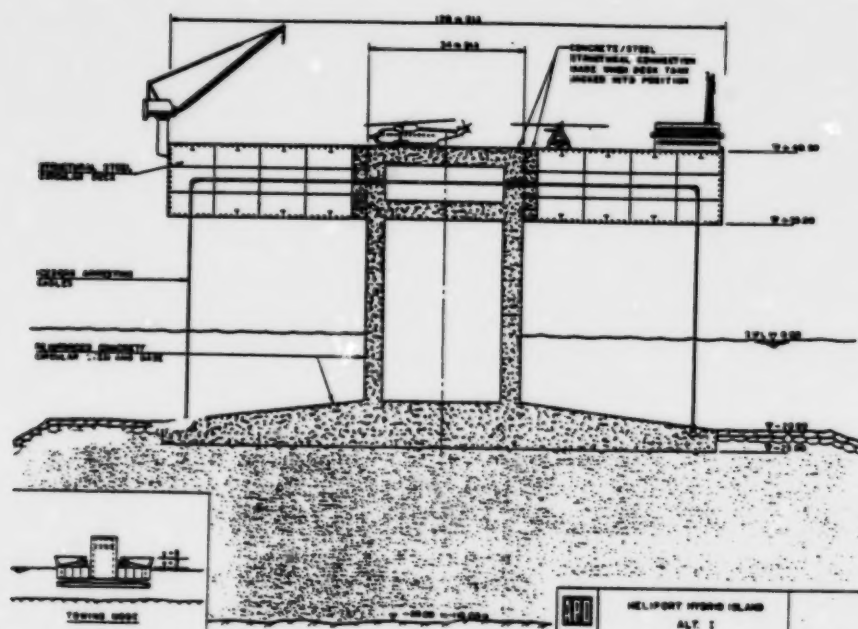
One possible method of construction aimed at reducing drydock requirements would be to fabricate only the bottom slab and a portion of the walls of the cellular base at a drydock. The partially finished base could then be floated to a trestle where the base and stem would be completed with the structure afloat. The tank deck, fabricated at a shipyard elsewhere, would be floated out in two sections, each mounted on one half a catamaran-type vessel constructed from two barge hulls. The catamaran barges would then be lowered by ballasting, (or falling tide used) to lower the tank sections onto the top of the base. The tank sections would then be permanently connected to form a single deck unit.

The cellular base would be designed to have sufficient buoyancy to support the completed structure during towing. With the deck tank in its raised position, the structure would be unstable and, as a result, would have to be towed with the deck tank lowered to a position immediately on top of the base as shown in the inset sketch on Figure 22. At the site the structure would be sunk by adding water ballast to the base, and as the structure sank, the deck tank would float around the stem providing the necessary lateral stability. Once founded on the berm, the cellular base would be fully flooded to increase its resistance to sliding and overturning. The deck tank would be raised on hydraulic jacks to its final position and the structural connection made between it and the concrete stem. Iceberg arresting cables would

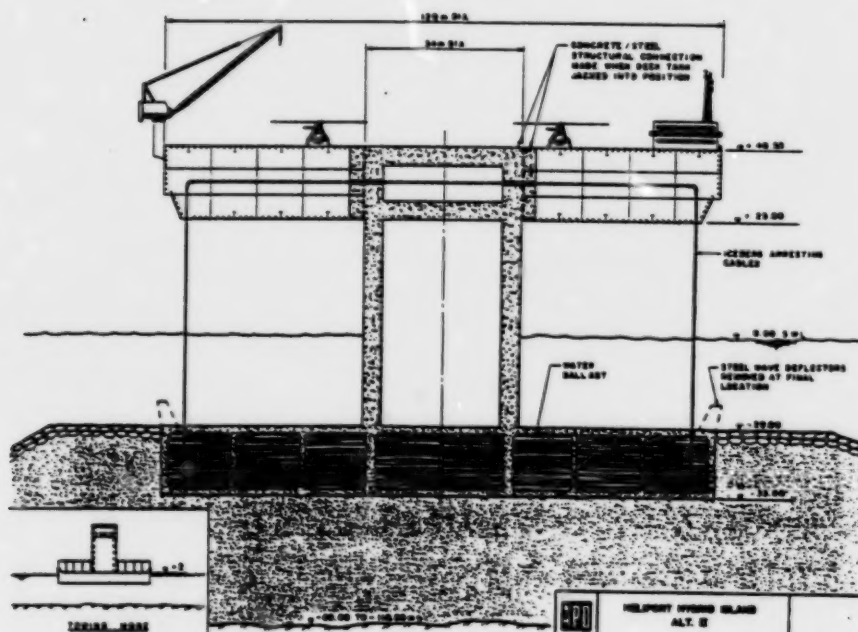
be fastened and the upper surface of the berm completed to its final elevation.

Similar material quantities are required as for Alternative 1. The estimated cost is also similar in range, and is estimated at \$560 million (Canadian).

Both structures can be built entirely in Canada using conventional construction techniques and facilities.



Alternative 1



Alternative 2

ARTIFICIAL ISLAND CONCEPTS: HELIPORT HYBRID ISLAND

figure 22

<u>Alternative 1</u>			
<u>Structure</u>			
Shore construction facilities			\$ 20,000,000
Concrete	105,000 m ³ @ \$400.00		42,000,000
Reinforcing steel	7,600 t @ \$1,500.00		11,400,000
Structural steel deck tank	10,300 t @ \$3,000.00		30,900,000
Iceberg fendering system			12,000,000
Superstructure and accomod.			3,000,000
Misc. equipment			3,000,000
Tow out & place			12,000,000
			<u>\$134,300,000</u>
	Engineering 3%		4,029,000
			<u>\$138,329,000</u>
	Contingency 15%		20,749,350
	SUB-TOTAL		<u>\$159,078,350</u>
<u>Underwater Berm in 80 m Water</u>			
Hydraulic fill	7 x 10 ⁶ m ³ @ \$20.00	\$140,000,000	
Armour	900,000 t @ \$250.00	225,000,000	
	SUB-TOTAL	<u>\$365,000,000</u>	
	Engineering	3,000,000	
		<u>\$368,000,000</u>	
	Contingency 10%	36,800,000	
		<u>\$404,800,000</u>	
			<u>\$563,878,350</u>
	TOTAL		<u>\$564,000,000</u>
<u>Alternative 2</u>			
<u>Structure</u>			
Shore construction facilities			\$ 20,000,000
Concrete	81,000 m ³ @ \$500.00		40,500,000
Reinforcing steel	7,600 t @ \$1,500.00		11,400,000
Structural steel deck tank	10,300 t @ \$3,000.00		30,900,000
Iceberg fendering system			12,000,000
Superstructure and accomod.			3,000,000
Misc. equipment			3,000,000
Tow out & place			12,000,000
			<u>\$130,800,000</u>
	Engineering 3%		3,924,000
			<u>\$134,724,000</u>
	Contingency 15%		20,208,600
	SUB-TOTAL		<u>\$154,932,600</u>
<u>Underwater Berm in 80 m Water</u>			
From Alternative 1			<u>\$404,800,000</u>
			<u>\$559,732,600</u>
	TOTAL		<u>\$560,000,000</u>

Construction Cost Summary
Heliport Hybrid Artificial Island
(\$1983 Canadian)

Table 31

9.2.4 Heliport Gravity Base Structure, Virgin Rocks

The Virgin Rocks formation is comprised of Prairie Shoal, Main Ledge and South Shoal. They have a length of 15 km and are located 200 km southeast of St. John's, and 150 km west-southwest of the Hibernia development area. The Virgin Rock heliport concept involves the sinking of a prefabricated deck and pedestal gravity base structure in 10m to 15m of water on Main Ledge. The existing rock formation would provide natural protection from most icebergs and deepwater waves.

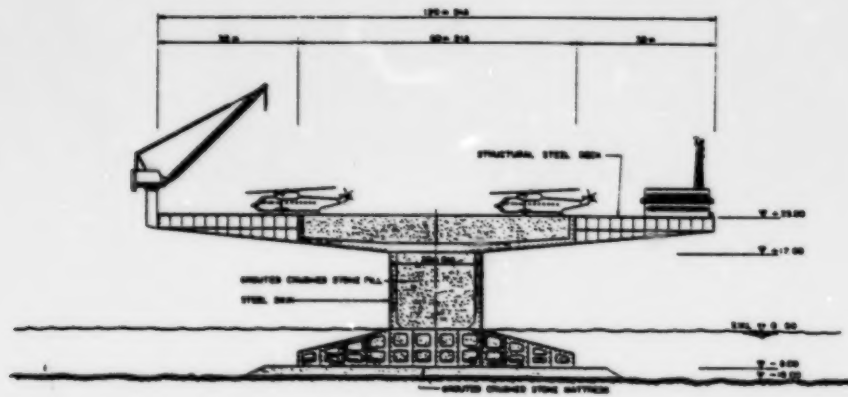
The shoal is assumed to be competent with some requirement for foundation preparation such as removal of irregular areas.

Both concepts have been designed to withstand the impact of a wave that can pass the 30m contour without breaking. Two concepts were considered for the heliport as shown in Figure 23. Alternative 1 assumes that an hour glass shaped structure would be constructed in two parts at a shipyard; a 120m diameter helideck, steel shell and a 60m diameter compartmentalized base. The base would be founded on a prepared crushed stone mattress placed atop the shoal. The core of the pedestal would then be filled with crushed stone and cemented with grout to prevent erosion and collapse. The annular steel deck would raise to its upper position and permanently connected to the pedestal.

Material requirements for this concept are estimated as 7,100 tonnes of structural steel, 40,000m³ of crushed stone fill, and 12,000m³ of cement grout. It would cost approximately \$95 million (Cdn).

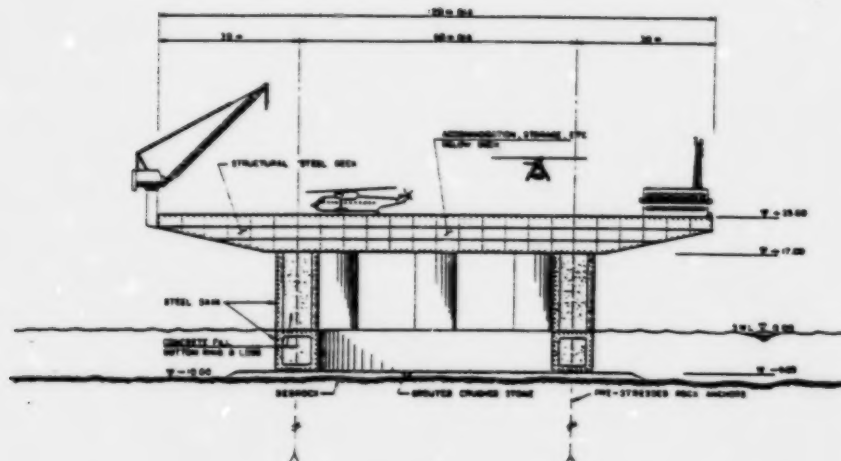
Alternative 2 envisages a submersible vessel design incorporating a 120m diameter helideck supported by eight circular legs, mounted on an octagonal base which would be founded atop a crushed stone mattress placed on the shoal. The base and legs would be concrete-filled and foundation anchors drilled into bedrock for increased safety against sliding and overturning.

The configuration of the structure provides sufficient stability to permit complete fabrication, including topsides, prior to towing out and setting.



APD HELIPORT GRAVITY STRUCTURE
VIRGIN ROCKS ALT. 1

Alternative 1



APD HELIPORT GRAVITY STRUCTURE
VIRGIN ROCKS ALT. 2

Alternative 2

ARTIFICIAL ISLAND CONCEPTS: HELIPORT GRAVITY STRUCTURE ON VIRGIN ROCKS

figure 23

Material requirements for this alternative are 9,300 tonnes of structural steel, 24,000m³ of fill concrete, 350 tonnes of prestressed anchor cables and fittings. Materials and labour costs are estimated at approximately \$95 million (Cdn).

<u>Alternative 1</u>		
<u>Structure</u>		
Onshore facilities		\$5,000,000
Structural Steel (onshore)	3,400 t @ \$4,000.00	13,600,000
(at site)	3,700 t @ \$5,000.00	18,500,000
Crushed stone fill and grout	40,000 m ³ @ \$ 500,000	20,000,000
Superstructure & accomod.		3,000,000
Miscellaneous equipment		3,000,000
Tow out and place		6,000,000
<u>Foundation</u>		
Rock removal	4,000 M ³ @ \$1,700.00	6,800,000
Place, screed and grout pad	4,000 m ³ @ \$1,000.00	4,000,000
SUB-TOTAL		\$79,900,000
Engineering 3%		2,397,000
		\$82,297,000
Contingency		12,344,550
		\$94,641,550
TOTAL		\$95,000,000
<u>Alternative 2</u>		
<u>Structure</u>		
Onshore facilities		\$5,000,000
Structural Steel (onshore)	9,300 t @ \$4,000.00	37,200,000
Concrete fill	24,000 m ³ @ \$ 500.00	12,000,000
Pre-stressed anchors & fittings	350 t @ \$7,000.00	2,450,000
Superstructure & accomod.		6,000,000
Tow out and place		6,000,000
<u>Foundation</u>		
From Alternative 1		\$10,800,000
SUB-TOTAL		\$79,450,000
Engineering 3%		2,383,500
		\$81,833,500
Contingency 15%		\$12,275,025
		\$94,108,525
TOTAL		\$95,000,000

Construction Cost Summary
Heliport Gravity Structure Virgin Rocks
(\$1983 Canadian)

Table 32

Both concepts could be fabricated in Canada. Design details are shown on Figure 23 and the costs are detailed in Table 32.

9.2.5 Venture Island

An artificial island, identified as Venture Island by its sponsors, is proposed for a site 10 km east of Sable Island, in 22m of water. The concept assumes a jointly owned, multi-use facility. The island would be a rock structure with a sand core, and would accommodate a sheltered marine harbour, helipad, STOL or RTOL runway and a variety of facilities including personnel accommodation, a search and rescue unit, a meteorological unit, and navigational facilities. Hydrocarbon storage and/or processing facilities, as well as defence and territorial resources management units could also be accommodated.

The concept involves the creation of an artificial berm containing some 13 million cubic meters of dredged sea bottom sand, which would be protected by one million tonnes of quarried rock, transported from a quarry located at the Straits of Canso. This armor rock would assist in the dissipation of wave energy and the grounding of (rare) icebergs. Depending upon industry requirements, the harbour, helideck or air strip could be constructed in phases to reduce initial costs. The complex could be constructed within 2-5 years, and would represent 100% Canadian content in terms of technological development, materials purchased and labour resources utilized. The foreseen advantages are:

- o provision of a fixed, stable, ice resistant platform near petroleum recovery activities;
- o joint ownership and cost sharing of related facilities and services;
- o provision of a permanent structure which could be adapted for other uses in future.

Its estimated cost is \$290 million. Design geometrics are shown on Table 33.

Total annual capital and operating costs of this concept were not estimated in detail but could fall within the range of the for the VLCC/STOLport barge concept discussed later. Its disadvantage relative to the barge concept is its lack of mobility. This disadvantage might be offset by its ability to serve as a permanent marine transportation hub. As such, it falls outside the terms of reference for this study, but merits further consideration as a special purpose, site specific solution.

<u>Runway</u>	- length	700 m.
	- width	100 m.
	- strip width	150 m.
(Optional) Crosswind runway		to be established
<u>Harbour</u>	- depth	15 m.
	- length	250 m.
	- width	200 m.
(Optional) Harbour		50 x 100 m.
<u>Island</u>	- elevation	12.5 m.ASL
	- length	800 m.
	- width	360 m.
(Optional) <u>Facilities:</u>		
Aircraft hangars, workshops, offices, storage		
NAV/COM/ATC/FSS/MET units		
Crew Accommodation		
Petroleum tank farm		
Emergency Services/SAR unit/hospital		
Defence, Fisheries management unit		

Venture Island Design Characteristics*

Table 33

* Actual design of island to be modified to suit site-specific requirements.

9.3 VLCC Heliport

This scheme involves the purchase of a surplus very large crude carrier (VLCC) or supertanker, and the conversion to a floating heliport. Its converted cost was estimated \$41 million (Cdn) as shown on Table 34.

The purchased tanker would be taken to a drydock where surplus deck equipment would be removed, and the main deck converted into a helipad. Maintenance, air traffic control, and navigational aid facilities would all be added, as would wave deflectors for sea spray diversion from the runway. A turret mooring system would also be installed.

Compared to the artificial island, helideck concepts described previously, the floating VLCC helipad will have reduced availability for aircraft landings because of extreme deck motion response under some sea-state conditions. To minimize this factor, the touchdown point could be located at the vessel's longitudinal centre of gravity, where movements would be much reduced. During extreme sea states or under threat of iceberg collision, the vessel would have to be disconnected from its anchors and relocated.

Purchase VLCC	\$ 4,000,000
Tow to drydock and to site	3,000,000
Clear deck and add 2m high deflector	4,000,000
Operating surface	500,000
Superstructure and accommodation	6,000,000
Misc. equipment	3,000,000
Dynamic positioning system	7,000,000
Anchor system	7,000,000
SUB-TOTAL	\$34,500,000
Engineering 2%	690,000
	\$35,190,000
Contingency 15%	5,278,500
	\$40,468,500
TOTAL	\$41,000,000

Construction Cost Summary
VLCC Helipad
(\$1983 Canadian)

Table 34

9.4 Tension Leg Heliport

The concept of a tension leg platform (TLP) for use as a heliport has been included in the study to provide a cost comparison with other alternatives.

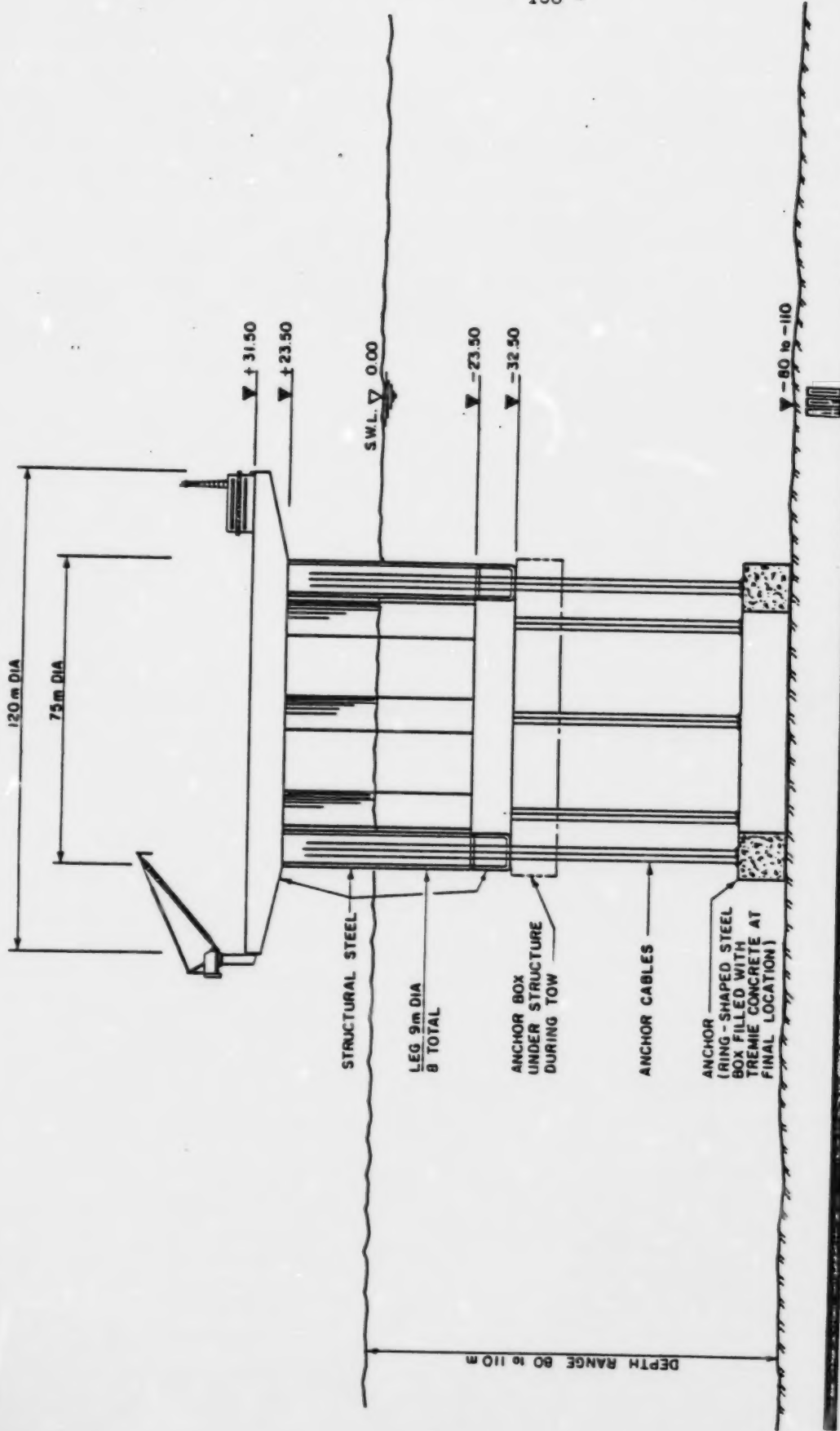
Figure 24 shows details of the platform which would be designed to operate in water depths ranging from 80m to 110m. The vessel is similar in some respects to a semi-submersible platform. It would be fabricated in structural steel and have an octagonal pontoon 9m by 9m in cross-section. Eight, 9m diameter legs would support the 120m diameter deck structure.

In this concept, the mooring system consists of a series of wire rope anchor cables which connect each leg to the gravity anchor. In some locations the anchorage could consist of piles driven into the seabed. The wire rope anchor cables would be contained in sheaths filled with a corrosion inhibitor. The gravity anchor could be fabricated as an open structural steel caisson, which, during vessel assembly, would be attached to the anchor cables and winched to the underside of the pontoon. The structure would be towed to the operating site in this configuration.

At the operating location the caisson would be lowered onto the seabed and filled with tremie concrete. The structure would be ballasted down and the slack in the anchor cables taken up. The vessel would then be deballasted to provide a pre-calculated tension in the cables, such that during the passage of a design wave of 36m, adequate tension would be maintained in the cables to prevent damaging jerking effects.

With this system, heave, pitch and roll movements are reduced almost to zero, although horizontal movements are still permitted. This low vertical response to wave action would provide close to 100 per cent availability of the heliport for aircraft operations.

As with other vessels, however, the platform would have to be disconnected and moved out of the area when threatened by extreme ice conditions and icebergs.



FLOATING HELIPORT CONCEPT: HELIPORT TENSION LEG STRUCTURE

figure 24

Estimated materials quantities for this concept are: structural steel 13,000 tonnes; anchor cables 1,300 tonnes; anchor caisson steel 2,200 tonnes; tremie concrete 30,000m³.

Its total cost is estimated at \$116,000,000 (Cdn) with a breakdown of costs shown as Table 35.

Onshore facilities		\$ 5,000,000
Structural Steel	13,000 t @ \$4,000.00	52,000,000
Anchor system		
- cables & equipment	1,300 t @ \$6,600.00	8,580,000
- structural steel	2,200 t @ \$3,000.00	6,600,000
- tremie concrete	30,000 m ³ @ \$ 300.00	9,000,000
Deck superstructure		3,000,000
Misc. equipment		3,000,000
Towing and anchoring		<u>10,000,000</u>
	SUB-TOTAL	\$ 97,180,000
Engineering 3%		<u>2,915,400</u>
		\$100,095,400
Contingency 15%		<u>15,014,310</u>
	TOTAL	<u>\$116,000,000</u>

Construction Cost Summary
Tension Leg Heliport
(\$1983 Canadian)

Table 35

9.5 Semi-Submersible Heliport Structure

Although the tension leg platform has a very low vertical motion response to waves, a comparable semi-submersible platform can also exhibit acceptably low motion response. The semi-submersible heliport is estimated to cost \$100,000,000.

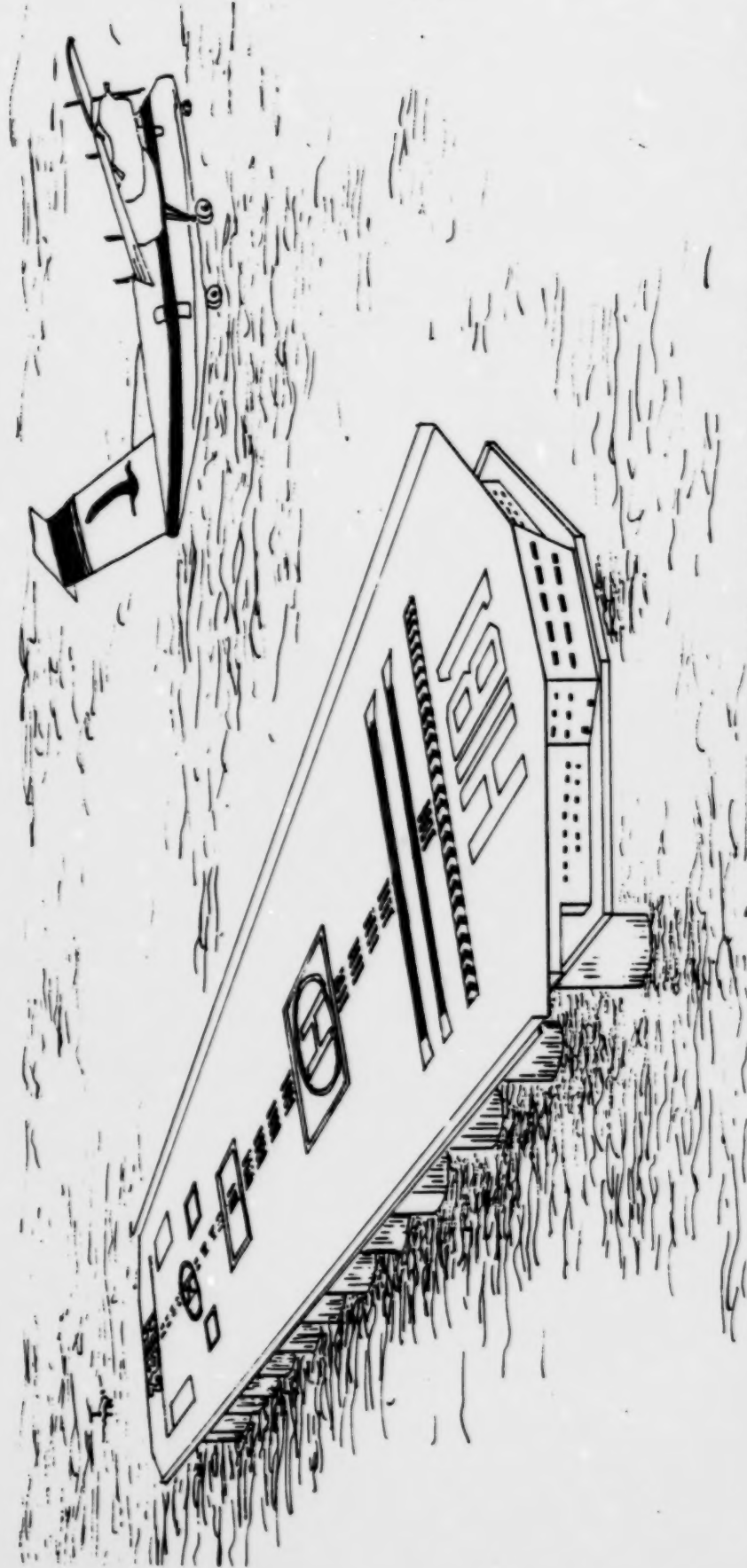
Computer analyses of the motion characteristics of this concept were carried out for this study but sufficient experience exists with helicopter operations from helidecks on semi-submersible drilling platforms to confirm the viability of the concept.

On a judgemental basis, it is felt that the sophistication of the tension leg platform may not be economically justifiable in terms of its use as an offshore heliport, when compared with the cheaper semi-submersible alternative.

9.6 Semi-Submersible STOLport

The concept of a floating, all-weather runway for fixed wing aircraft operations on the high seas already has wide military applications. However, a carrier with the dimensions required to support the 90m wide by 602m long runway for Dash-7 operations has not been built to date. In addition to providing the runway, navigational and other facilities related directly to aircraft operations, the vessel must also provide for other related facilities such as aircraft hangars, vehicle parking, maintenance shops, fuelling, personnel accommodations, survival equipment, medical facilities, and storage. Equipment related to the transfer of fuel and other supplies from support vessels would also be required. In the Seaforth Maritime concept aircraft related facilities and equipment would be accommodated on the second of three main deck levels, while crew accommodation would be located below, on the third level. Emergency response equipment and medical facilities are strategically sited throughout the vessel for rapid deployment.

The Seaforth Maritime design is depicted on Figure 25. It has a turret mooring system to allow the vessel to rotate 360 degrees so under most wind conditions the runway will "weather vane" and head into the prevailing wind, the most desirable orientation for aircraft operations. In some instances, strong seas may cause the vessel to



Seaforth Maritime Limited / The deHavilland Aircraft of Canada

SEMI-SUBMERSIBLE STOLPORT

figure 25

swing out of the wind but this condition may be at least, partly compensated for by the use of dynamic positioning equipment to realign the runway with the wind.

<u>PRINCIPAL DIMENSIONS</u>	
Length Over Runway	602.0 m
Breadth Over Runway	90.0 m
Depth to Lower Deck	41.0 m
Depth to Lower Tween Deck	44.0 m
Depth to Upper Tween Deck	47.0 m
Depth to Runway	51.0 m
Operational Draught	23.0 m
Survival Draught	19.0 m
Runway Height Above Sea Level (operational)	28.0 m
<u>DESIGN CHARACTERISTICS</u>	
Deadweight	78,952 tonnes
Light Ship	96,968 tonnes
- crew and other accommodation 450 or 800 people - maximum wave height of 31.3 m with an association duration range of 16.3 to 19.5 seconds - all welded steel construction employing DE and Z quality steel or equivalent - deck to be supported by 26 columns extending from bottom of pontoons to runway deck - 28 lifeboats - Watercraft Type MK III TESC or equivalent accommodating 75 persons each - inflatable capsules and diving facilities - survival gear - 4, 35 tonne anchors, 111 mm chain cable, wire rope with 4 electric drive winches and stowage - 8 twin-barrel general purpose hydraulic, 2 speed winches - ballast tanks and associated pumps, piping and control mechanisms - fresh water and fuel systems - 2 aircraft lifts 27 x 30 m with associated motors - 4 store cranes - runway marking, fittings, arrestor gear - firefighting equipment - 14 AC generators for main and auxiliary propulsion - 10 constant speed controllable pitch vector thrusters - 2 C.P. propellers diameter 5000 mm - hangars, stores, workshops	

Semi-Submersible STOLport Design Characteristics

Table 36

A proposed optional feature is that the vessel be self-propelled to allow it to reposition itself and to shorten travel distances to the various offshore platforms. Under threat of ice and iceberg collision, such a vessel could remain off anchor in readiness to move from the area. During periods of calm, the vessel would be able to create its own "wind" to improve aircraft handling, and in fog it could seek out areas of improved visibility. If self-propulsion capability is not included the attendance of a support vessel would be required.

The vessel will respond to the action of waves in terms of translatory and angular displacements, velocities and accelerations. The configuration of the vessel determines the level of these responses in terms of deck action which in turn imposes limits on the operation of aircraft during take-off and landing. Generally, flying conditions rather than vessel motion will be the cause of STOLport downtime.

The extreme seastate in the three geographical areas of the study is considered to comprise waves of the order, $H_{\text{significant}} = 18\text{m}$ and at extreme, $H_{\text{max}} = 36\text{m}$, with wave duration periods greater than 20 seconds for a return period of 100 years. Wave lengths equal to the length of the vessel are therefore possible. Structure and anchor integrity must be maintained under these conditions. Ballast and free-board requirements are designed to ensure that structural stresses and occasions of deck-wettings are minimized.

Other extreme environmental events to be considered are sea ice and icebergs. At present, floating exploration vessels are disconnected and moved out of the area when under the threat of ice or icebergs. Theoretically, the floating runway can be reinforced to withstand the forces imposed by sea ice and some icebergs. The weak link however, is the anchor, since it is doubtful that an effective system can be feasibly designed to withstand the heavy forces required to hold the vessel against all ice forces. Therefore, when threatened with ice or icebergs, the floating airport would be disconnected and moved from the threatened area. Under most circumstances, it would be possible to

relocate to a pre-designated position within operating range of helicopters serving the exploration and production platforms.

Due to the near continuous ice cover and prevalence of icebergs in the Labrador Sea, operation of a floating runway at this location would be limited to the summer months. On the Grand Banks the facility could usually operate throughout the year although frequent disconnections could be necessary when under threat of collision with icebergs or in years when sea ice cover is severe. On the Scotian Shelf disconnection resulting from ice or iceberg threat should be infrequent.

The capital and operating costs of the semi-submersible STOLport as estimated by the Norwegian Ship Institute are shown in Table 37.

<u>STOLport including floater</u>		NOK 1200-2500 million
Personnel - Maritime crew		58 persons
Airport staff		66 persons
Subcontract personnel (floater, airport, maintenance)		<u>83</u> persons
	Total	207 persons
Wages and overhead per day		NOK 142,000
Travel and Consumables per day		NOK 12,000
Annual Cost		NOK 56.21 million
<u>Annual Fuel</u> Consumption-1500 sec Redwood		108 tons/day
Cost NOK 1200/ton		NOK 47.3 million
<u>Annual Maintenance</u> (hull and airport)		
Repair and Maintenance		NOK 19.20 million
Survey Cost		<u>16.80</u> million
	Total	36.00 million
<u>Annual Insurance</u>		NOK 13.20 million

Capital & Operating Costs
Semi-Submersible STOLport
(Foreign Drydock) (1981)

Table 37

* 5.9 Norwegian Krone = \$1 Canadian (1983)

Due to the size of the vessel, integral construction would only be possible at foreign drydocks although modular construction in Canada would be possible. The cost estimates for the concept is between 1200 to 2500 million (1981) Norwegian Krone or \$203 to 423 million Canadian (1981) as shown in Table 37.

For the purpose of this study the Capital costs were adjusted for escalation and set at \$472 million Canadian. This value resulted in a cost differential of \$100 million over that of the comparable all new STOLport barge, a differential judged reasonable considering the greater complexity of sophistication of the semi-submersible vessel. However, it is fair to say that a fully reliable estimate is not available. The complexity of the concept is such that the costing exercise by itself would be a significant undertaking requiring funds and personnel not considered justified for purposes of this study at this time.

A possible variation of this concept is the addition of a floating hotel or "floatel" unit. Crew dormitories, cafeteria, recreational facilities, hospital, and workshops could be established within the lower levels of the semi-submersible vessel. A cost breakdown for two sizes of floatel units are listed in Table 38.

1. STOLport Facility	450 bed unit	800 bed unit
Operating Cost	14.6	14.6
Catering Cost	33.7	59.9
Annual Total Cost**	48.3	74.5
2. Charter of Separate Facility	450 bed unit	800 bed unit
Operating Cost	29.9	59.8
Catering Cost	33.7	59.9
Fuel Cost	56.0	112.0
Capital Cost	102.4	204.8
Annual Total Cost	222.0	436.5

Cost Comparison*

STOLport/Separate Floatel Facility (NOK million 1985)

Table 38

* 5.9 Norwegian Krone = \$1 Canadian (1983)

** Excludes full and capital costs already substantially included in the cost of the main hull.

9.7 Seaforth Maritime STOLport Barge

The concept envisages combining a STOL runway with a floating crude oil storage facility. A floating oil storage and loading facility is under consideration for service off of Canada's east coast. One scenario considered is the mooring of a centrally located IMM barrel oil storage and loading facility to serve a number semi-submersible production platforms, each anchored directly over a well cluster. Each platform could have the capacity of processing 50,000 barrels of crude oil daily for transfer via submarine pipeline and common riser to the storage vessel. Oil from the storage vessel could then be transferred to land-based terminals using shuttle tankers of heavy capacities in the order 80,000 Dead Weight Tonnes.

Through further research, Seaforth Maritime have developed a rectangular barge concept of special geometry which displays motion characteristics, equal to or better than those of the semi-submersible concept. The concept is shown on Figure 26. The length, beam and displacement of the barge are selected to provide optimum motion response under design sea states. The concept is sometimes referred to as a "tuned" barge. The barge configuration is more suited than the semi-submersible concept to conventional shipyard construction methods, with a resultant reduction in cost. The barge also lends itself to the dual function of STOLport operations and crude oil storage. Total cost of the facility is estimated to be \$374,000,000 (Cdn).

Combining a floating runway with oil storage facilities in one vessel has both positive and negative implications. A vessel capable of supporting a runway, 602m long by 90m wide, has very large potential oil storage capacity. Storage in excess of that normally considered economical in a storage-only vessel can be provided at marginal costs to reduce the sensitivity of delays in the shuttle tanker service. Also, depending upon the actual layout of the production platforms, a reduction in the number of storage vessels required in any one area may be possible.

One of the major concerns with combining aircraft operations with oil storage is possible risk of explosion and fire. In addition to providing adequate fire-fighting equipment and techniques, major reductions in risk can be achieved by storing the oil in central tanks protected on all sides by water ballast tanks. It would be especially important but not necessarily mandatory to have this separation immediately under the runway deck. The water ballast tanks could also provide a double skin to protect against pollution of the environment in the event of damage arising from a collision. Ventilation of oil tanks would involve procedures similar to those presently employed on oil tankers. In these applications, inert gas is maintained at overpressure in the storage tanks at all times, and the concentration of the gas is kept below its explosive limit during venting.

The large numbers of transient personnel on board, would necessitate special security precautions.

To obviate the need for oil/water separation facilities on the storage vessel, oil storage and water ballast tanks would be separated by rigid bulkheads or by flexible membranes.

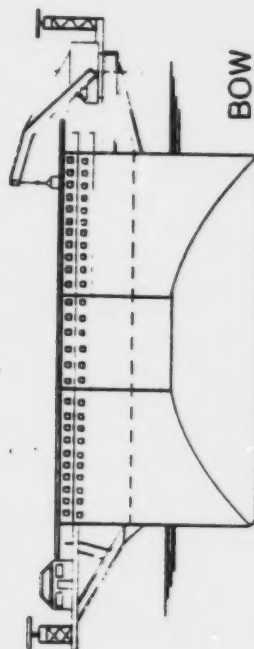
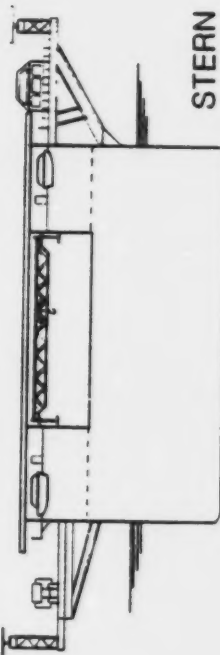
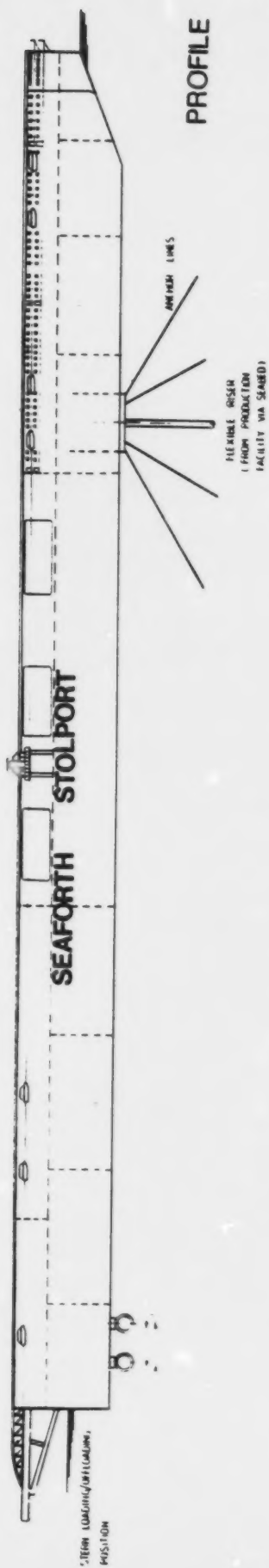
Several riser/anchor systems being used by exploration and storage vessels including a turret-mooring system, and a single anchor leg system. With the former, the turret forms a moonpool through which the riser arrangement passes. The turret is anchored to the seabed with several anchor lines so that both the turret and the riser system remain stationary as the vessel weather-vanes around them. To move the vessel from the area, the riser must be disconnected at the base and raised in the moonpool to clear the seabed. Quick-release hooks are deployed to release the anchor lines, which have buoys attached for retrieval for reconnecting.

In the single anchor leg system, the riser passes up through a single column which is connected via a universal joint to a base on the sea-

bed. A yoke connects the bow of the vessel to the column through a gimbal and swivel arrangement which allows the vessel to weather-vane. In a disconnect situation the vessel with the yoke attached moves off the column. This requires that provision is made for adding ballast to the column and lowering it into an excavated trough in the seabed below the reach of bottom-scouring icebergs.

The riser/mooring system for a vessel of this size has not been built, but its construction is considered to be within the scope of present technology. A trade off between the cost of providing structural integrity and the losses associated with unavailability of the system in heavy seas may be necessary. In a given seastate, the relatively rigid yoke/column arrangement will tend to induce higher mooring forces than the turret-mooring system and, therefore, may necessitate vessel disconnect at lower wave heights. The yoke-column disconnect and reconnect procedure takes place on the sea surface, and is more simple to effect than those for the turret system, which involves the reeving of several anchor lines through the turret, and the reconnection of the riser on the seabed.

The obstruction to aircraft created by the superstructure of the shuttle tanker can be eliminated by using specially designed shuttle vessels with, for example, those with telescopic masts. Alternatively, shuttle tanker and aircraft schedules can be co-ordinated under IFR conditions to avoid conflict.



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AND SEAFORTH MARITIME LIMITED

FLOATING STOLPORT CONCEPTS: **TUNED BARGE**

figure 26

Structural Steel	85,000 t @ \$3,000.00	\$ 255,000,000
Turret mooring		10,000,000
Misc. equipment & facilities		<u>50,000,000</u>
	SUB-TOTAL	\$315,000,000
	Engineering 3%	<u>9,450,000</u>
		\$324,450,000
	Contingency 15%	<u>48,667,500</u>
		\$373,117,500
	TOTAL	<u><u>\$374,000,000</u></u>

Construction Cost Summary STOLport Barge
(\$ 1983 Canadian)

Table 39

Barge Length	570 m
Width	76 m
Depth	41 m
Design Draught	18 m
Flight deck (upper level) length	602 m
width	90 m
- 16 crude oil storage tanks - total capacity	380,000m ³
- oil storage - midship	
- aircraft hangars - aft or midship - Level 3	
- segregated ballast tanks - Level 3	
- inert gas system	
- 30 bed hospital with operating theatre	
- computer room	
- meteorological facilities	
- crew and other accommodation	up to 320 People
- survival equipment & high speed emergency rescue launch	
- shielded arrestor nets	

Tuned Barge Design Characteristics

Table 40

9.8 VLCC Barge

The surplus of oil supertankers (VLCCs) on the world market has caused their resale value to drop to the range of \$4 million to \$14 million (Cdn). This has created interest in the conversion of these tankers into offshore drilling and production vessels, floating oil storage, and other applications.

The concept of modifying and reinforcing hulls of 250,000 DWT oil tankers for service as a floating runway has been investigated as part of this study. Figure 27 shown the proposed layout of the scheme.

A 602m long by 90m wide runway could be constructed atop a vessel that is 105m wide by 550m long. This would require that five VLCC hulls be cut into sections which would then be connected end to end and side by side to form the STOLport hull. To permit airport operations in extreme seastates the hull sides would be raised by 10m in order to increase bending and shear capacity, and to reduce the incidence of deck-wetting. The vessel, which would be approximately double the length of the original tanker would be further reinforced by adding a steel plate to the bottom, sides and deck, to ensure that the steel stress levels do not exceed those of the original tanker hull.

The elevated runway would be of steel plate construction, resting on supports. The surface would be coated to improve traction and increase skid resistance. The raised sides would provide a safety barrier for aircraft during landings and a deck mounted arresting mechanism would be installed near the bow for emergency deployment.

To maintain an unobstructed runway, navigational and other equipment would be mounted in the raised sides. Elevator platforms would be provided to transport aircraft, and mobile vehicles to hangars and maintenance bays below the deck, where personnel accommodation, sick bay, storage and other services are located.

Fuel, stores and other supplies would be transferred from surface vessels by an overhead travelling crane at the stern.

It is anticipated that the vessel will remain at the same location for long periods, during which time the vessel would be anchored with a turret mooring system.

This concept would require five VLCC supertankers, 25,000 tonnes of structural steel for hull reinforcement, and 5,500 tonnes of steel for runway construction. Its total cost is estimated to be \$250,000,000 (Cdn). Tables 41 and 42 show the comparison of costs for construction in the Far East and in a temporary Canadian drydock.

VLCC Barge with Oil Storage and Loading Facilities

The floating STOLport built from VLCC tanker hulls lends itself to the inclusion of crude oil storage facilities, since tanks, piping and valving for water ballast and oil are inherent in the basic design.

For STOLport purposes, plate reinforcement would be required, to be added to the deck and bottom, to increase the bending capacity of the hull over a length of 150m at the mid-section of the vessel. This reinforcement, together with some additional stiffeners, could be added at the appropriate locations below the deck and above the keel to form water ballast tanks. If the wing tanks also were used for water ballast storage, the central oil storage tanks would be protected on all four sides. The hydrostatic pressure created by the surrounding ballast water would inhibit oil leakage from the crude oil tanks.

Purchase	5 ea. VLCCs @ \$4,000,000	\$ 20,000,000
Tow tankers to shipyard	5 ea. VLCCs @ \$1,800,000	9,000,000
Cut up sections and weld new steel	25,000t @ \$4,000.00/t	100,000,000
Cantilever ends		5,000,000
Runway steel + skid-resistant coating		27,000,000
Superstructure and accommodations		3,000,000
Propulsion system		18,000,000
Misc. equipment		3,000,000
Tow to site		16,000,000
Anchor system		10,000,000
	SUB-TOTAL	\$211,000,000
	Engineering 3%	6,330,000
		\$217,330,000
	Contingency 15%	32,599,500
		249,929,500
	TOTAL	<u>\$250,000,000</u>

Construction Cost Summary
VLCC Barge (Far-East Drydock)
(\$1983 Canadian)

Table 41

From Table 41	SUB-TOTAL	\$ 211,000,000
Deduct "Tow to site"		<u>- 11,000,000</u>
		\$ 225,000,000
Construct temporary drydock on east coast Canada:		
Mobilize and Demobilize	\$ 1,000,000	
Clear overburden & excav. rock	720,000m ³ x \$10.00	7,200,000
Gran. base & drainage	72,000m ³ x \$15.00	1,080,000
Gate steel	600t x \$3,000.00	1,800,000
Gate monolith concrete	800m ³ x \$500.00	400,000
Dykes	18,000m ³ x \$20.00	360,000
Concrete pedestals	2,250m ³ x \$500.00	1,125,000
Pumping & gate movements		2,000,000
Infrastructure, roads, camps etc.		
	15,000,000	
	<u>\$ 29,965,000</u>	<u>\$ 30,000,000</u>
	SUB-TOTAL	\$ 225,000,000
	Engineering 3%	<u>7,650,000</u>
		\$262,650,000
	Contingency 15%	<u>33,217,500</u>
		\$ 302,047,500
	TOTAL	<u><u>\$302,000,000</u></u>

Construction Cost Summary
VLCC Barge (East Coast Temporary Drydock)
(\$1983 Canadian)

Table 42

The oil storage capacity that could be made available over the 150m length of hull is 223,000m³ (1,750,000 barrels). With the arrangement depicted on Figure 27, sufficient ballast capacity would exist in the

water tanks independent of oil storage. Therefore, during oil off-loading, water would not have to be introduced into the oil storage tanks, thereby obviating the need for a flexible separating membrane or water/oil separation facilities.

If additional storage were required, the central wing tanks could be used for this purpose, increasing storage capacity by $82,000\text{m}^3$ (650,000 bbl) to $303,000\text{m}^3$ (2,400,000 bbl). To maintain the transverse structural integrity of the hull cross-section, water ballast would have to be introduced into the wing tanks simultaneously with oil unloading. Alternatively, the wing tanks could be used for oil storage exclusively, in which case additional steel reinforcement of the the vessel cross-section would be required.

Oil storage capacity could also be increased by lengthening the oil tanks. This would require additional steel to form the top and bottom water ballast tanks. Storage could be provided at a rate of $1,500\text{m}^3$ (11,800 bbl) per metre of vessel length, at a corresponding increase in steel requirements of 25 tonnes per metre. By re-arranging the steel plate reinforcement required for hull strengthening, the floating STOL-port could provide oil storage of approximately $223,000\text{m}^3$ (1,750,000 bbl). Storage for up to eight days production from one to four production platforms each with a daily process capacity of $6,370\text{m}^3$ (50,000 bbl) could be provided. Doubling of storage to 3.5mm bbl would require 3,750 tons of additional steel for the protective top and bottom ballast tanks at an incremental cost of \$11,000,000. Additional costs of modifications to piping and valving would also be involved. These and other costs are listed in Table 43.

<u>1. VLCC Barge with 223,000m³ (1,750,000 bbl.) Storage Capacity</u>	
Sub-total from Table 41	\$ 211,000,000
Additional valving, piping etc.	<u>10,000,000</u>
SUB-TOTAL	\$221,000,000
Engineering 3%	<u>6,630,000</u>
	227,630,000
Contingency 15%	<u>34,144,500</u>
	261,774,500
TOTAL	<u><u>\$ 262,000,000</u></u>
<u>2. VLCC Barge with 446,000m³ (3,500,000 bbl.) Storage Capacity</u>	
Sub-total from Table 41	\$ 211,000,000
Additional steel 3,750 tonnes @ \$3,000.00	11,250,000
Additional valving, piping etc.	<u>12,000,000</u>
	\$234,250,000
Engineering 3%	<u>7,027,500</u>
	241,277,500
Contingency 15%	<u>36,191,625</u>
	277,469,125
TOTAL	<u><u>\$ 278,000,000</u></u>
* Vessel only, riser system not included.	

Construction Cost Summary
VLCC Barge with Oil Storage &
Loading Facilities*
(\$1983 Canadian)

Table 43

VLCC Barge Construction

The efficient cutting up and assembling of the hull sections of five supertankers requires that the vessels be of similar design and configuration. The vessels need not be sister ships but they should be so proportioned and constructed that the matching of bulkheads and framing can be accomplished without abrupt changes between sections. A brief review of tanker registries indicates that several similar vessels have been built, although a further survey is required to determine their construction details and their availability on the surplus market.

The selected vessels would be towed to a drydock for stripping of the superstructure and deck-mounted piping and equipment. The tankers would then be cut up into sections, which would be reassembled to form the hull of the floating runway. Hull reinforcement, propulsion systems and dynamic positioning equipment would be added. In the absence of fitting-out wharf facilities, the vessel construction could be completed out of drydock, (runway construction, piping and valving modifications, the addition of hangars and the like).

The vessel could then either travel under its own power, or would be towed to its offshore location.

An alternative to having the vessel built in a foreign shipyard would be to construct a temporary drydock facility on the east coast of Canada. The drydock should be of the graving dock type, excavated on shore, in a sheltered location.

One scheme examined was to excavate, in rock, an area 125m wide by 600m to an elevation of 10m below water depth. A rock plug would left in place on the shore to permit dock construction to be completed in the dry; a layer of crushed stone would be placed on the floor of the drydock as a working surface; plinths to support the keels of the VLCCs during modifications to the hulls would be constructed from reinforced

concrete; the gate structure and earthfill cofferdams would then be built, and finally the dewatering system would be installed. Once the dry dock was complete, the rock plug would be removed flooding the drydock and the VLCCs would be floated into position. The gate, which would be of structural steel or reinforced concrete would be floated over the sill, and ballasted into place. The drydock would then be dewatered. Assistance in the handling of materials would be provided by two large, railmounted cranes, which would travel at grade level on each side of the dock.

The drydock would have to be dewatered and flooded several times in the course of hull construction to allow, floating out scrapped sections, aligning, positioning, and the welding of sections into the complete hull. Since the drydock would not be not a commercial operation with a waiting list of customers, all works could be completed in the dock.

A gate opening of 60m would be required to permit passage of a single VLCC hull. When the 105m wide STOLport vessel is complete, the drydock would be flooded, and the gate structure demolished. The earthfill dykes would be removed to the full width of the dock opening to allow the vessel to be floated out.

9.9 Semi-Submersible Catamaran

The semi-submersible catamaran or Swath vessel, depicted on Figure 28, is based on a Japanese design by Mitsui. The vessel is a high speed, twin pontoon personnel carrier, suitable for shuttle operations between either fixed or floating platforms, or for emergency rescue. Semi-submersible catamarans currently in special use such as for hydrographic surveying, have an estimated cost of \$40 million and a passenger capacity for 300 people. Typical design characteristics for vessels capable of operating off of the east coast are:

o length (over pontoons)	71.5m
o beam (overall)	41.7m

o operational draught	13.5m
o displacement	5,790 ft (1760m)
o motion characteristics	good, low motion

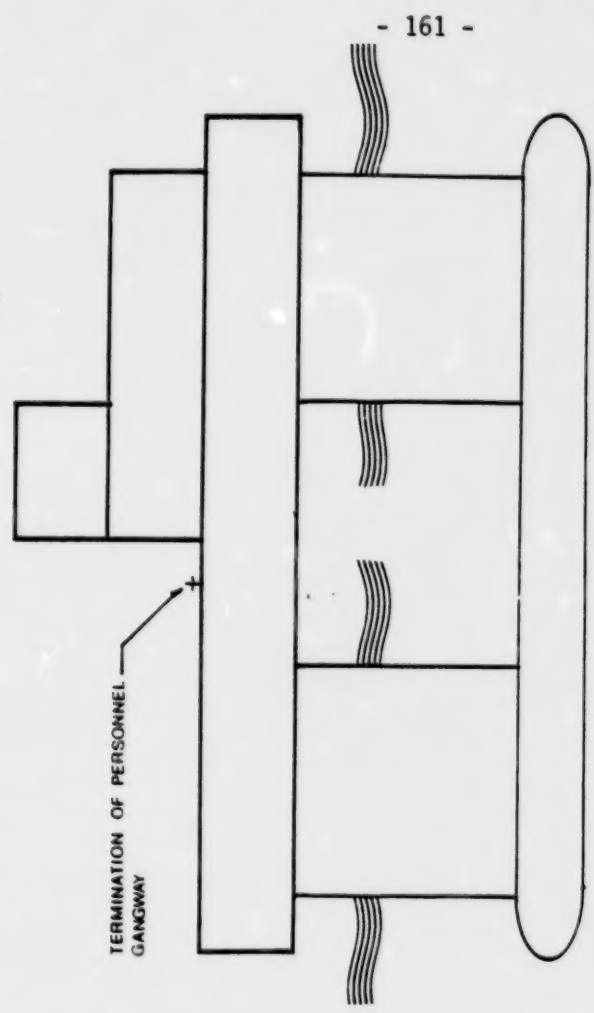
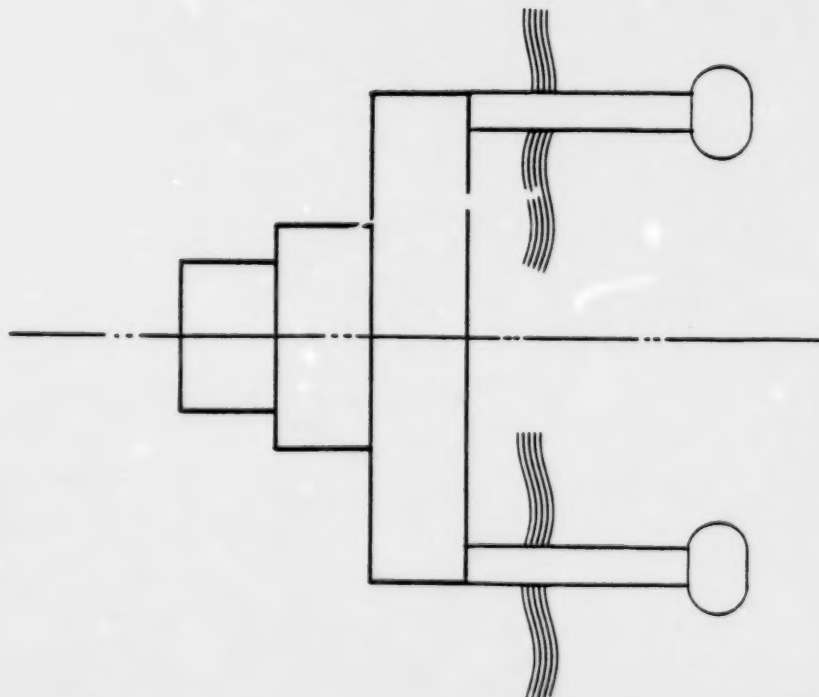
Features of British and Japanese versions are listed in Table 44.

Transfer Gangway

A transfer gangway is proposed for use in conjunction with the SWATH vessel. This flexible evacuation ramp can be utilized in most weather conditions for connecting between floating or fixed structures. The concept is depicted in Figure 29.

Operational tolerances for the gangway associated with motion displacement between the mid-ship area of the floating STOLport tuned barge, and a SWATH vessel are:

- o 2m vertical deviation during normal operations
- o 4m vertical deviation for the extreme event, corresponding to a 7.4m wave height and 18.6m/s wind speed. The latter condition occurs in each of the three study areas approximately 0.6% of the time. Additional detail appears on Table 45.



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APD

SWATH PERSONNEL CARRIER SCHEMATIC

figure 28

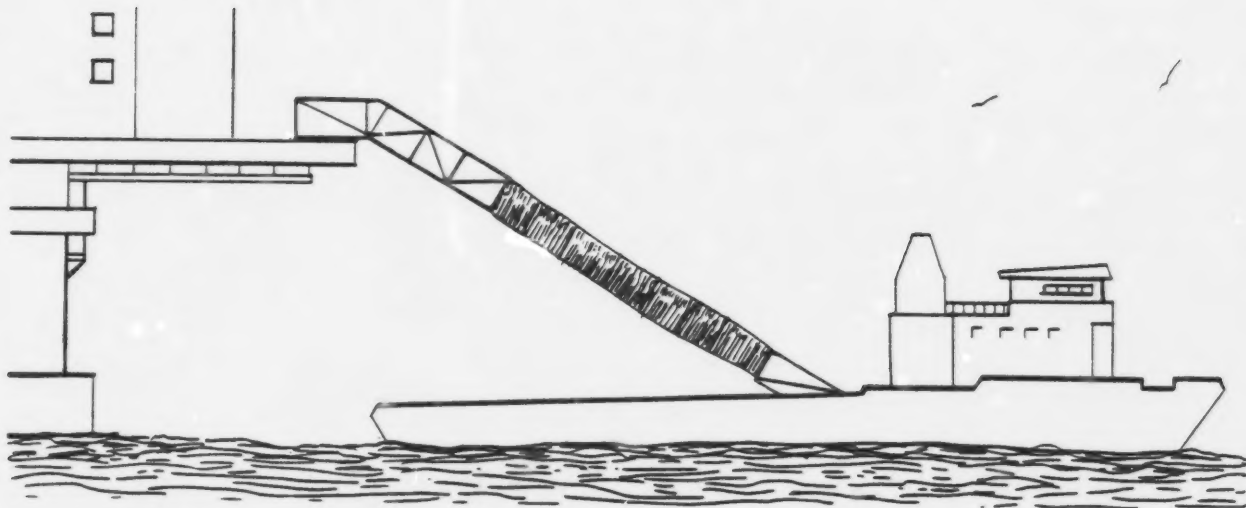
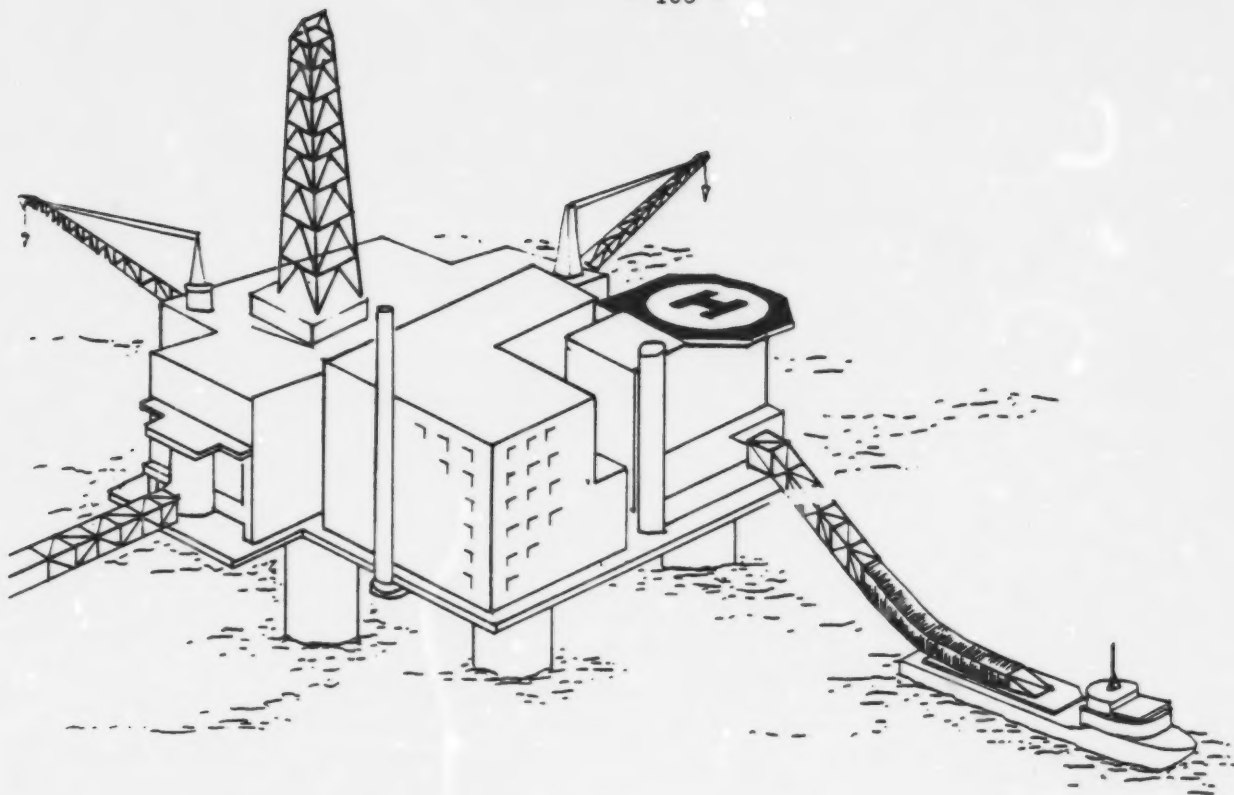
1. <u>Japanese Version</u> ²⁶	
Overall - length	35.9 m.
- breadth	17.1 m.
- depth	5.8 m.
- design draft	3.1 m.
Gross tonnage	670 tons
Maximum Speed	27 knots
Passenger Capacity	446 people
Crew Requirement	7 people
Helideck on stern (3 sizes of swath carriers available)	
2. <u>British Version</u> ²⁷	
- length	30.2 m.
- width	15.25 m.
- load draft	4.3 m.
Displacement	310 tons
Cruise Speed - Economical	25 knots
Maximum Speed	28 knots
Endurance	12-16 hours at full speed
Passenger Capacity	300 people
Crew Requirement	6 people
Fuel Requirement	36 tons

Swath Vessel Design Characteristics

Table 44

²⁶ Mitsui Engineering & Shipbuilding Co. Ltd., Mitsui Semi-Submerged Catamaran (SSC) for Offshore Personnel Transport, MI-82201 Tokyo, April, 1982.

²⁷ Condos Marine Consultants Limited, Conceptual Study into the Role of the Swath Ship for Offshore Duties, Cumbria U.K. 1981.



Puñes

GANGWAY TRANSFER SYSTEM

figure 29

MONTH	NEWFOUNDLAND SHELF	LABRADOR SEA	SCOTIAN SHELF
January	97%	96%	95%
February	95%	95%	95%
March	97%	96%	97%
April	98%	100%	99%
May	99%	100%	99%
June	99%	99%	99%
July	99%	99%	99%
August	100%	99%	99%
September	99%	99%	98%
October	98%	97%	99%
November	97%	99%	98%
December	95%	96%	96%

Percentage Availability of
Vessel for Personnel Transfer
(Significant Wave Height 7.4m)

Table 45

9.10 Motion Response

9.10.1 Seaforth Maritime STOLport Barge

The motion response characteristics of the STOLport Barge have been investigated for wave heights ranging from 3m to 15m and corresponding periods of 6 seconds to 12 seconds in head and quartering seas. Table 46 shows these motion results.

The vessel displays extremely low levels of motion in severe seastates. In head seas, the single amplitude response in a 15m significant wave, which approximates to a 100 year storm condition, is characterized by a heave of 3.1m and a pitch of 0.54 degrees, a slope of 1:100 approximately. In quartering seas, these responses increase slightly to a heave of 3.5m and pitch of 0.62 degrees.

Of particular interest is the motion of the runway at the touchdown point of the Dash-7, 100m from the threshold.

Typically, the Dash-7 aircraft has a vertical closing speed of 1 to 2m/sec. prior to touchdown. The undercarriage is designed to withstand the impact at a vertical speed of 3m/sec. Therefore, the permissible upper limit of closing vertical speed of the runway at touchdown point is approximately 1.5m/sec.

Table 47 shows the vertical velocity of the vessel at touchdown point for head and quartering seas for various significant wave heights and periods. These figures have been manually computed from computer printouts results and, although approximate, are sufficiently accurate for this conceptual study. These figures indicate that a vertical velocity of 1.5m/sec. occurs in head seas at a significant wave height of around 11m and in quartering seas at a significant wave height of around 10m.

These statistics are representative of vessel response only. Other factors, such as fog, wind, icing and the like have to be superimposed to determine overall availability of the system.

HEADING (deg.)	WAVE HEIGHT (m)	SURGE (m)	SWAY (m)	HEAVE (m)	ROLL (deg.)	PITCH (deg.)	YAW (deg.)
180	3	0.019	0.001	0.046	0.000	0.007	0.000
	6	0.103	0.004	0.359	0.001	0.060	0.001
	9	0.253	0.008	0.982	0.002	0.164	0.001
	12	0.467	0.016	1.980	0.003	0.338	0.003
	15	0.681	0.026	3.123	0.004	0.544	0.004
157.5	3	0.020	0.047	0.048	0.022	0.007	0.006
	6	0.104	0.193	0.411	0.053	0.068	0.027
	9	0.240	0.409	1.080	0.086	0.179	0.061
	12	0.426	0.817	2.226	0.129	0.381	0.132
	15	0.601	1.308	3.545	0.182	0.619	0.218

STOLport Barge
Significant Response Amplitude

Table 46

WAVE HEIGHT	PERIOD	VERTICAL VELOCITY (m/sec.)	
		HEADING	
		180°	157.5°
3	6.0	0.065	0.074
6	8.0	0.443	0.510
9	9.5	1.024	1.131
12	11.0	1.812	2.054
15	12.0	2.657	3.020

STOLport Barge Vertical Velocity at Touchdown Point

Table 47

Another important consideration for aircraft is the pilot's perception of the vertical movement of the runway. An out-to-out movement of 6m is considered the maximum permissible for safety.

Table 48 shows the out-to-out vertical movement of the runway threshold for various significant wave heights and corresponding periods in head and quartering seas. The results indicate that the limiting vertical movement of 6.0m occurs at a significant wave height of 11m in head seas and 10m in quartering seas.

A comparison of the above wave heights with those significant wave heights producing maximum permissible vertical velocities shows that both limiting conditions for aircraft landing are reached at approximately the same wave height.

WAVE HEIGHT (m)	PERIOD (sec)	OUT-TO-OUT VERTICAL MOVEMENT (m)	
		HEADING	
		180°	157.5°
3	6.0	0.146	0.166
6	8.0	0.334	1.536
9	9.5	3.666	4.046
12	11.0	7.526	8.538
15	12.0	12.060	13.716

STOLport Barge Vertical Movement at Threshold

Table 48

By inspection, it can be seen that the percentage availability of the vessel for aircraft landing in significant waves of 10m and 11m ls, for all three areas would approach 100 percent on an annual basis and between 97 percent to 99 percent for the winter months.

A detailed breakdown of percentage availability for all three geographical areas is shown in Table 49.

MONTH	NEWFOUNDLAND SHELF	LABRADOR SEA	SCOTIAN SHELF
January	99%	99%	98%
February	99%	100%	99%
March	99%	97%	98%
April	100%	100%	100%
May	100%	100%	100%
June	100%	100%	100%
July	100%	100%	100%
August	100%	100%	100%
September	100%	100%	99%
October	100%	99%	100%
November	100%	100%	100%
December	100%	98%	99%

Percentage Availability of
Vessel for Landing
(Significant wave height 10m & 11m)

Table 49

9.10.2 VLCC Barge

Method of Analysis

A frequency domain mooring analysis was performed on the VLCC barge to determine the response of the system in eighteen seastates. The responses were computed using the computer program OSCAR which is an acronym for Ocean System Computer Analysis Routines. The input consisted of barge characteristics, seastates and mooring line information.

Input Data and Assumptions

The barge was assumed to be rectangular in shape with a length of 550m, beam of 92m and a height of 27m. The centre of gravity (C.G.)

was assumed to be at $x = 275\text{m}$, $y = 0.0\text{m}$ and $z = 6.36\text{m}$ with a ballasted weight of 420,000 tonnes. The draft was therefore calculated to be 7.4m and the trim angle as zero degrees. The three radii of gyration were assumed as follows: $R_x = 29.3\text{m}$ and $R_y = R_z = 159.1\text{m}$. The vertical metacentric locations were calculated by OSCAR and remained fairly constant at 91.5m.

The type of mooring assumed was a single point system allowing the vessel to rotate 360 degrees about a gravity anchor with a 1,500m long anchor cable and a holding capacity of 2,700 tonnes. The cable's dry weight was estimated to be 150 kg. per metre; the cross-sectional area 195cm^2 ; the modulus of elasticity 83,000 MPa. The water depth was assumed to be 92m. The anchor line tensions were calculated on the basis that the line formed a catenary between the barge and the anchor.

Using the Mean Jonswap spectrum, eighteen seastates of irregular seas formed the statistics for all of the vessel's response operators. Significant wave heights varied from 1.5m to 18.3m with periods ranging from 9 seconds to 20 seconds as follows in Table 50.

The seas were assumed to be uni-directional (head seas) and long crested. The calculations were based on standard spectral techniques with linearity assumed; statistics output assumed that the peaks are Rayleigh distributed. Wind loads were neglected.

SIGNIFICANT WAVE HEIGHT (m)	PERIODS (sec.)
1.5	9 - 12
2.4	9 - 12
3.4	10 - 13
4.0	10 - 13
4.6	12 - 15
9.1	12 - 15
12.2	14 - 18
15.2	16 - 20
18.3	16 - 20

Wave Height/Duration Relations

Table 50

WAVE HEIGHT (m)	PERIOD (sec.)	SURGE (m)	SWAY (m)	HEAVE (m)	ROLL (deg.)	PITCH (deg.)	YAW (deg.)
1.5	9	0.067	0.000	0.552	0.000	0.068	0.000
1.5	12	0.125	0.000	0.809	0.000	0.128	0.000
2.4	9	0.107	0.000	0.888	0.000	0.108	0.000
2.4	12	0.200	0.000	1.305	0.000	0.202	0.000
3.4	10	0.172	0.000	1.514	0.000	0.177	0.000
3.4	13	0.278	0.000	1.775	0.000	0.274	0.000
4.0	10	0.204	0.000	1.786	0.000	0.210	0.000
4.0	13	0.329	0.000	2.096	0.000	0.323	0.000
4.6	12	0.376	0.000	2.432	0.000	0.378	0.000
4.6	15	0.407	0.000	3.585	0.000	0.408	0.000
9.1	12	0.765	0.000	4.797	0.000	0.751	0.000
9.1	15	0.833	0.000	7.099	0.000	0.811	0.000
12.2	14	0.998	0.000	7.460	0.000	0.940	0.000
12.2	18	1.735	0.000	10.450	0.000	1.655	0.000
15.2	16	1.537	0.000	11.784	0.000	1.430	0.000
15.2	20	2.669	0.000	15.261	0.000	2.544	0.000
18.3	16	1.840	0.000	13.893	0.000	1.688	0.000
18.3	20	3.201	0.000	18.261	0.000	3.048	0.000

VLCC Barge - Significant Response Amplitudes

Table 51

WAVE HEIGHT (m)	PERIOD (sec.)	VERTICAL VELOCITY (m/sec.)
1.5	9	0.371
1.5	12	0.433
2.4	9	0.597
2.4	12	0.698
3.4	10	0.931
3.4	13	0.972
4.0	10	1.101
4.0	13	1.147
4.6	12	1.316
4.6	15	1.367
9.1	12	2.661
9.1	15	2.737
12.2	14	3.537
12.2	18	3.293
15.2	16	4.294
15.2	20	4.090
18.3	16	5.078
18.3	20	4.880

VLCC Barge - Vertical Velocity
at Touchdown Point

Table 52

Since the mooring system provided only one restraint for one degree of freedom, sway, roll and yaw were required to be held fixed. Initially, a static run was made to estimate the anchorline tension for a 4.6m, 12 second wave, thus providing an initial anchor tension which facilitated in locating the initial equilibrium position. Once the first equilibrium position and response operators were found, the environment was changed until all of the seastates had been run.

Results

The motion response of the VLCC barge for various significant wave heights and corresponding periods is shown in Table 51. The vertical velocity of the barge at touchdown point for various significant wave heights and corresponding periods are shown in Table 52. These figures indicate that a vertical velocity of 1.5m/sec. at the touchdown point occurs at a significant wave height of 5m in head seas.

The percentage availability of the vessel for aircraft landing is as shown in Table 53.

MONTH	NEWFOUNDLAND SHELF	LABRADOR SEA	SCOTIAN SHELF
January	89%	90%	86%
February	89%	89%	89%
March	86%	93%	91%
April	92%	98%	95%
May	97%	100%	98%
June	98%	98%	99%
July	99%	99%	99%
August	98%	98%	98%
September	95%	94%	97%
October	92%	91%	97%
November	87%	92%	92%
December	84%	89%	89%

Percentage Availability of
Vessel for Landing (Significant wave height 5m)

Table 53

As noted previously, the computer input data was selected early in the study. Subsequent refinement of design parameters resulted in increasing the operating draft to 20m. The corresponding increase in ballast weight has the effect of improving the dampening characteristics of the vessel and its response to seastate. Given conceptual nature of the study, it is felt that an additional computer runs to recalculate all values was not warranted. Since the VLCC Barge and STOLport Barge have very similar configurations and dimensions, their motion response characteristics and therefore availability would not be dissimilar.

De Havilland have indicated that with a strengthened undercarriage the limiting vertical velocity of the Dash-7 at touchdown can be increased to around 3.7m/sec., which would increase the allowable vessel vertical velocity from 1.5m/sec. to 2.2m/sec. approximately. This would have the general effect of increasing availability by 2 to 5 percentage points.

Both the STOLport Barge and VLCC Barge exhibit good availability based on aircraft landing criteria only. Overall availability of the system is obtained by the superimposition of the effects of such factors as fog, wind and icing.

9.11 Navigational Aids - Marine

Navigational aids such as Loran A, and Loran C may be adapted for use with the various STOLport concepts, or SWATH vessels, to assist in marine navigation and operations.

Marine advisories are available through Canadian Coast Guard Vessel Traffic Management Centres in the area.

No special facilities were identified as being required for any of the floating STOLport concepts considered.

9.12 Sable Island STOLport

It is possible that a substantially less expensive STOLport could be constructed on Sable Island, particularly as the beaches are presently being used by fixed wing aircraft with balloon tires²⁸. This is site-specific solution and its potential impact on aviation transport in the vicinity of the Scotian Shelf is addressed in Chapter 11.

²⁸ Mobil Oil Canada Ltd., Venture Development Project Environmental Impact Statement Vol. 1 to 4. Halifax, February, 1983.

10.0 EVALUATION OF ALTERNATIVE AVIATION SYSTEMS

10.1 Introduction

The principal criterion used for evaluating the options for air transportation was cost, on a total system basis. This included capital and operating costs for all three system elements including:

- o the offshore airport
- o the first stage air service serving the offshore airport facility from the mainland, and
- o the second stage shuttle, by rotary wing aircraft or marine vessel from the offshore airport to the production platforms.

Annual capital and operating costs (in constant \$ 1983 Canadian) were calculated for passenger traffic volumes ranging from 25,000 annual, one-way person-trips to 300,000 annual, one-way person-trips for each of the following three categories of aviation systems:

1. The Base Case, utilizing rotary wing aircraft to transport personnel directly from the onshore base to the offshore platforms.
2. Floating STOLport Systems, utilizing Dash-7 aircraft for the first stage transfer of personnel from the shore to a floating STOLport, followed by a shuttle service by helicopter or marine vessel, as the second stage of transfer, from the STOLport to the production platforms. The STOLport concepts included in this evaluation were:
 - o Seaforth Maritime Semi Submersible STOLport
 - o Seaforth Maritime STOLport Barge or "Tuned Barge" with crude oil storage
 - o VLCC STOLport Barge
 - o VLCC STOLport-Crude Oil Storage Barge Combination
3. Offshore Heliport Systems, serving as a transfer base for a two stage helicopter service, or as an alternate heliport under IFR weather conditions. The heliport concepts evaluated were:
 - o Artificial Island

- o Gravity Structure (Virgin Rocks)
- o VLCC Helipad
- o Tension Leg Structure
- o Semi Submersible Structure

Initial comparisons were made assuming ideal operating conditions for all systems, ignoring delays due to weather or mechanical problems. In these comparisons only primary costs and benefits were considered. Secondary benefits were assessed only as modifying factors where applicable. Secondary considerations included:

- o potential benefits from non-transportation activities
- o impact of weather delays
- o flexibility

10.2 Offshore Airport Capital and Operating Costs

10.2.1 Cost Summary

The relevant costs for the floating STOLport alternatives are summarized on Table 54 for the floating STOLport alternative, and on Table 55 for the Heliport Alternatives. The estimating methodology and the assumptions underlying these costs are outlined under the following headings:

- o Capital Recovery and Interest;
- o Crew;
- o Fuel;
- o Maintenance;
- o Insurance;
- o Aviation Electronics.

ITEM	SEMI SUBMERSIBLE STOLPORT	STOLPORT BARGE	VLCC BARGE	VLCC BARGE (1.75mm bbl storage)	VLCC BARGE (3.5mm bbl storage)
A. Capital Cost	472	374	250	262	278
B. Annual Capital Recovery & Interest	68.9	54.8	36.5	38.2	40.6
C. Crew	7.1	7.1	7.1	7.1	7.1
D. Fuel	7.9	3.2	3.2	3.2	3.2
E. Maintenance	6.1	5.6	3.7	3.9	4.1
F. Insurance	2.0	1.9	1.3	1.3	1.4
G. Aviation Electronics	1.2	1.2	1.2	1.2	1.2
TOTAL	93.2	73.8	53.0	54.9	57.6

Annual Capital and Operating Cost Summary
Floating STOLports
(\$ Millions Canadian 1983)

Table 54

ITEM	ARTIFICIAL ISLAND HELIPORT	VIRGIN ROCK HELIPORT	VLCC HELIPORT	TENSION LEG HELIPORT	SEMI SUBMERSIBLE HELIPORT
A. Capital Cost	560	95	41	116	100
B. Annual Capital Recovery & Interest	81.8	13.9	6.0	16.9	14.6
C. Crew	3.8	3.8	6.6	4.4	4.4
D. Fuel	0.5	0.5	3.2	1.0	1.0
E. Maintenance	8.4	1.4	.6	1.7	1.5
F. Insurance	2.8	.5	.2	.6	.5
G. Aviation Electronics	1.2	1.2	1.2	1.2	1.2
TOTAL	98.5	21.3	17.8	25.8	23.2

Annual Capital and Operating Costs
Offshore Heliports
(\$ Millions Canadian 1983)

Table 55

10.2.2 Capital Repayment and Interest

The estimated capital costs for the alternative floating STOLport are shown on Table 56. The cost estimates for the Seaforth Maritime semi submersible concept are based on a 1981 estimate (\$ 414 million) escalated by 14% to reflect 1983 costs. All other costs are based on new estimates (1983 \$ Canadian) prepared specially for this study, and include engineering costs and a 13% contingency allowance. The heliport cost estimates are summarized on Table 57.

Annual capital and interest payments were calculated by the Capital Recovery Factor (CRF) method, where:

$$CRF = \frac{i (1+i)^n}{(1+i)^n - 1} = 0.146$$

Where i , is the annual rate of interest, assumed to be 12%, and
 n is the repayment period, assumed to be 15 years.

Combined annual capital and interest payment equals:

$CRF \times \text{Facility Total Capital Cost}$

FACILITY	DESCRIPTION	CAPITAL COST	COMMENT
1. Seaforth Maritime STOLport Barge	Complete including 3.0mm bbl oil storage	\$374	Includes turret mooring system
2. VLCC Barge	STOLport facilities only (no crude storage)	\$250*	Includes aviation system & towing
3. VLCC Barge	STOLport facilities - Canadian East Coast construction	\$302	Includes temporary dry dock
4. VLCC Barge	STOLport facilities plus 1.75mm bbl crude oil storage	\$262*	Vessel only Riser system not included
5. VLCC Barge	As for 4 above except 3.5mm bbl crude oil storage	\$278*	Vessel only Riser system not included
6. Seaforth Maritime Semi Submersible STOLport	Composite estimate no floating facilities	\$472	1981 estimates range from \$200 million (Harland Wolfe)** to \$414 million Aker Group***

Capital Cost Summary
Floating STOLport Alternative
(\$ Million Canadian 1983)

Table 56

* Far East Construction
 ** Ulster
 *** Norway

FACILITY	DESCRIPTION	CAPITAL COST	COMMENT
Artificial Island	Heliport placed on artificial island	\$560	Set on underwater berm below sea level
Virgin Rock Heliport	Gravity Structure	\$95	Placed 25m below sea level
VLCC Heliport	Modified VLCC Tanker	\$41	Includes dynamic positioning & anchor system
Tension Leg Heliport		\$116	
Semi submersible Heliport		\$100	Includes anchor System

Capital Cost Summary
Offshore Heliport (\$ Million Canadian 1983)

Table 57

10.2.3 Fixed Overhead

In 1981, Seaforth Maritime estimated that annual insurance costs for the semi-submersible STOLport would be in the order of 0.5% of its total capital cost. This rate was assumed to apply equally to all other STOLport and Heliport facilities considered in this study.

Seaforth Maritime also estimated that the annual maintenance and survey costs for the semi submersible vessel would be of the order of 1.5% of the total capital cost of the vessel. This rate was assumed to apply equally to all other marine concepts being evaluated.

10.2.4 Fuel

The Seaforth Maritime estimate for fuel consumption for the semi submersible STOLport is 108 tons per day. Assuming a cost of \$200 per ton, the annual fuel cost for its free floating facility would be \$7.9 million.

The floating STOLport barges would remain anchored and would therefore consume less fuel. Their fuel costs, including power generation are estimated at 40% of that for the semi submersible or approximately \$3.2 million annually. This figure was also assumed to apply to the floating heliport concept. Fuel requirements for heating and power generation for the fixed heliports are estimated at \$0.5 million annually and for tension leg and semi-submersible facilities, \$1.0 million annually.

10.2.5 Crew Costs

Crew costs were calculated under three separate headings; marine crew, airport staff and support staff. There are wide variations in salary and overhead costs associated with the operation of marine vessels, and it is not clear at this time who would be responsible for the operation of the offshore airports. Personnel employed on drilling platforms can cost in the order of \$30 - \$35 per hour including wages, payroll costs, overheads, travel and accommodation. On the other hand, permanent crews on ships and tankers often cost less depending upon the country of vessel registry, union agreements, tenure and pension guarantees.

Seaforth Maritime estimated that wage costs for the semi submersible STOLport crew, operating in the North Sea would, on average, be of the order of \$250 (1981 Cdn. dollars) daily including wages, overhead, travel and consumables. Catering was estimated to cost an additional \$25 daily, per person.

For purposes of this study, three categories of crew costs were estimated as follows:

Category	\$/day (total)*
Marine crew	\$290
Airport staff	\$315
Support staff	\$245

* Includes \$25.00 day catering allowance.

The higher rate for the airport staff reflects the greater proportion of skilled trades associated with aircraft and electronic equipment maintenance.

Seaforth Maritime estimate the total marine crew requirements for a 24 hour operation for the semi-submersible, STOLport to be 58 persons. This figure was assumed to apply to all STOLports and the VLCC heliport under consideration. The Tension Leg heliport was assumed to carry a marine crew of 30 (excludes crew on standby tug). Marine crews were not assumed for fixed heliports but operating and maintenance staff requirements were estimated at 20 people.

CATEGORY	FUNCTION	STAFF POSITIONS	
		HELIPORT	STOLPORT
Manager	Controls airport operations	1	1
Technicians	Aircraft, landing aids, communications maintenance	8**	9**
Support	Runway maintenance, apron services, emergency response	3	4
Flight operations	Dispatch, ATC, MET, FSS	2	3
TOTAL		14	17

Offshore Airport Staff Requirements
(Person/Day)*

Table 58

* Assumes single 12 hour shift daily for aircraft operations and double shift for aircraft maintenance.

** Requirements dictated primarily by shuttle helicopter operations.

The estimated airport staff requirement for STOLport and heliports are tabulated on Table 58. These figures were developed on the basis of information obtained from local aviation operators.

The contract support staff requirements of the semi submersible STOLport were estimated at 83 persons by Seaforth Maritime. However, this estimate was based on a high level of personnel services and floatel accommodation, which while desirable, appear to exceed minimum requirements. For purposes of this study the ratio of support staff to marine crew and airport staff combined was assumed to be 0.5 compared with the Seaforth Maritime estimate of 0.67.

FACILITY	MARINE CREW	AIRPORT STAFF	SUPPORT STAFF	TOTAL
Floating STOLports	58	34	46	138
VLCC Heliport	58	28	43	129
Tension Leg Heliport	30	28	28	96
Fixed Heliport	20	28	24	72

Personnel Requirements

Table 59

FACILITY	\$ MILLIONS (Cdn.)
Floating STOLports	7.1
VLCC Heliport	6.6
Tension Leg Heliport	4.4
Semi submersible Heliport	4.4
Fixed Heliports	3.8

Annual Crew Costs

Table 60

10.2.6 Miscellaneous Costs

Standby Tug

The tension leg and semi submersible heliports will require a tugboat on continuous duty at an estimated annual cost of \$1.4 million. Other concepts might also require such assistance at least on a part-time

basis. In the event, this cost was ignored since it was assumed that tugs would probably be available as part of the support equipment for the production facilities:

Navigation Aids

The life cycle of precision electronics equipment under offshore conditions is difficult to predict, but given the harsh environment and related obsolescence factors, a seven year average life appears reasonable. Similarly, maintenance, calibration and certification costs are also difficult to calculate but have been estimated as 5% of the capital cost of each facility annually. This figure excludes the cost of on-vessel technician time, which has been allowed for separately in the estimate of crew costs. The capital and annual costs for offshore electronic facilities are shown in Table 61 and Table 62.

FACILITY	\$ 1983 CANADIAN
Peripheral (PAL Communication)	\$ 312,000
Offshore VOR/DME	490,000
M.L.S. & Precision DME	3,592,000
TOTAL	\$4,394,000

Capital Costs of
Offshore Electronic Facilities

Table 61

ITEM	\$ 1983 CANADIAN
Capital recovery and interest (7 years, 12% interest)	\$963,000
Maintenance, Calibration & Certification	\$219,000
TOTAL	\$1,182,000

Annual Costs for Offshore Electronic Facilities

Table 62

10.3 Floating STOLport Systems Cost Comparisons

10.3.1 Methodology

The combined capital and operating costs of each of the 5 alternative floating STOLport systems were compared against Base Case costs for each of the three potential offshore petroleum producing areas under consideration. The base case costs include rotary wing aircraft standby and operating costs only, and assume continuation of current practice.

The floating STOLport system costs included the following:

- o Fixed wing aircraft (Dash 7) shuttle costs for transporting personnel between the shore base and the floating STOLport (Stage 1).
- o Rotary aircraft shuttle costs for transporting personnel between the floating STOLport and the individual offshore platforms (Stage 2).
- o STOLport combined fixed and operating costs.

The base case and floating STOLport systems costs were compared over traffic levels ranging from 25,000 to 300,000 person trips annually. The lower figure represents offshore based employment of approximately 480 persons on two week rotation, and the upper figure, approximately 5,800 based employment assuming the same rotation period. The upper traffic figure was selected to encompass the breakeven level of demand for a semi-submersible STOLport at the Hibernia field and is believed to be well beyond current expectations.

Still air conditions were assumed to prevail and no allowances were initially made for any costs of delays either to equipment or to passengers. The effect of potential delays was subsequently assessed through a sensitivity analysis described in Chapter 11.

10.3.2 Service Level Assumptions

The operating concept for the floating STOLport assumes that it would be located within a 15 minute helicopter block flying time range of the employment centroid for the area being served. The transportation of passengers would take place in two stages, as follows:

Stage 1 - A common Dash-7 shuttle service between the shore base and the floating STOLport.

Stage 2 - A common helicopter shuttle service between the floating STOLport and the individual production platform.

The Stage 1 Service would operate at least 260 days annually. In order to provide some flexibility to cope with delays annual operations were set not to exceed 300 days annually.

No allowance was made in the costing for Dash-7 back-up, the assumption being that spare aircraft would be available in the operator's fleet, or failing this, a limited helicopter back-up would be available from the shuttle helicopters based on the STOLport or elsewhere in the system.

The shuttle helicopters were assumed to be S61Ns and were assumed to be serviced and maintained on the floating STOLport. A minimum of two helicopters would be based offshore. No cost allowance was made for substitute helicopters to cope with breakdowns, but an allowance was made for ferrying costs between the floating STOLports and the onshore bases for major overhaul and crew transfer.

10.3.3 Selected Base Case Operating Costs

The Base Case analysis is detailed in Chapter 7. The practical range of service and demand level assumptions for purposes of systems evaluation were established to be as follows:

Range of platform size	- 100-200 based employees
Staff Rotation Period	- 2 or 3 weeks
Minimum Flight Frequency	- 182 days annually
Number of Platforms per flight circuit	- 2
Load Factor	- 85% Average

The employee transportation costs computed on a one way person trip basis for each of the three geographical areas covered by the study are summarized in Table 64. The costs for the practical service range are contained within the heavy outline. For comparison purposes, the optimum transportation cost, defined as the cost that would be incurred if there were no schedule constraints, are also shown for each case. For each case, upper and lower cost limit was estimated.

The range of likely unit transportation costs for the assumed base case service are summarized as follows.

SYSTEM	ONSHORE BASE(S)	MAX. UNIT COST	MIN. UNIT COST	AVERAGE UNIT COST
Hibernia	St. John's	439	367	403
Labrador Sea	Hopedale	229	163	196
	Cartwright	313	232	272
Scotian Shelf	Halifax	331	275	253
	Halifax/Sydney	377	282	329
	Halifax/Sydney/ Yarmouth	451	363	407

Summary of Base Case
One Way Person Trip Costs (Dollars)

Table 63

STAFF ROTATION PERIOD (weeks)	HIBERNIA SYSTEM*					LABRADOR SEA**- CARTWRIGHT BASE				
	PLATFORM SIZE (EMPLOYEES)					PLATFORM SIZE (EMPLOYEES)				
	75	100	150	200	300	75	100	150	200	300
1	379	368	355	350	346	246	232	219	212	205
2	428	403	380	367	355	300	275	246	232	206
3	474	439	402	399	390	350	313	272	253	232
OPTIMUM PERSON TRIP COST	346					203				

STAFF ROTATION PERIOD (weeks)	LABRADOR SEA**- HOPEDALE BASE					SCOTIAN SHELF - HALIFAX				
	PLATFORM SIZE (EMPLOYEES)					PLATFORM SIZE (EMPLOYEES)				
	75	100	150	200	300	75	100	150	200	300
1	175	164	152	148	144	283	274	265	259	254
2	219	198	175	163	153	323	303	284	275	265
3	261	229	195	181	163	360	331	302	288	273
OPTIMUM	144					253				

Base Case Helicopter Transportation Costs
(Dollars Per Person Trip (Minimum Service Alt. Days)
(Likely Practical Operating Range in Box)

Table 64

Continued overleaf

STAFF ROTATION PERIOD (weeks)	SCOTIAN SHELF-HALIFAX/SYDNEY*					SCOTIAN SHELF-HALIFAX/SYDNEY/ YARMOUTH				
	PLATFORM SIZE (EMPLOYEES)					PLATFORM SIZE (EMPLOYEES)				
	75	100	150	200	300	75	100	150	200	300
1	297	281	266	257	250	393	363	334	319	304
2	361	328	298	282	265	509	451	392	363	334
3	422	377	327	304	281	626	537	451	405	362
OPTIMUM	247					284				

Base Case Helicopter Transportation Costs
(Dollars Per Person Trip (Minimum Service Alt. Days)
(Likely Practical Operating Range in Box)

Table 64

*Common Service - 2 platforms

**Shuttle Service - Single
Platform

Note - Arrow in box indicates upper and lower costs for likely operating range.

10.3.3.1 Offshore-Based Helicopter Shuttle Operating Costs

Equipment Requirements

The aircraft providing the STOLport based helicopter shuttle service would overnight at the STOLport. The second stage transfer helicopter service would be linked with the Dash-7 schedule in order to minimize the size of the STOLport-based helicopter fleet. A minimum of two 22 seat helicopters (21 persons plus attendant) would be available to handle each flight. A helicopter round trip was assumed to require 45 minutes.

For traffic demand levels of up to 12 Dash-7 movements daily, a schedule frequency of 1 hour between landings was assumed for estimating helicopter requirements. Thereafter, flight frequency was assumed to increase progressively to a maximum of one landing, on average, every 45 minutes during the Dash-7 operating period. A tighter schedule was not considered since a 45 minute flight frequency appeared adequate to meet the maximum assumed demand of 300,000 one way person trips annually. Helicopter requirements were estimated to be as follows:

ONE-WAY PERSON TRIPS ANNUALLY (000's)	DAILY DASH-7 LANDINGS AND TAKEOFFS COMBINED	NO. OF HELICOPTERS REQUIRED	AVERAGE ANNUAL BLOCKHOURS PER HELICOPTER
25	2	2	294
50	4	2	336
75	6	2	583
100	8	2	735
150	12	2	1028
200	16	3	980
250	20	4	882
300	24	4	1028

Aircraft Requirements

Table 65

Standby & Hourly Cost Estimates

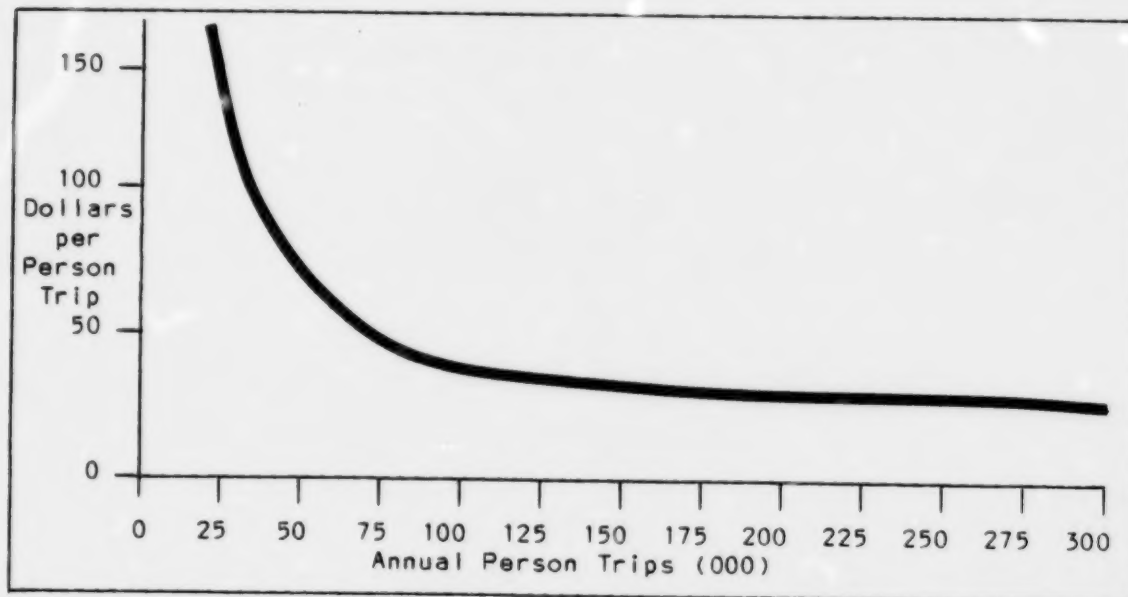
The annual standby and hourly costs for the offshore based helicopter shuttle operation were obtained by adjusting the costs previously developed for onshore based operations. The principle changes were to increase pilot costs and to delete technician costs; the latter being allowed for in the STOLport operating cost estimates. The estimated costs for the S61N follow.

COST CATEGORY	
A: STANDBY	\$1,000 PER ANNUM
Crew : Pilots	192
Attendant	40
Sub-Total	132
Depreciation	255
Insurance	180
Interest	190
Management	300
Profit	300
Onshore Support, ferrying costs & misc.	425
TOTAL FIXED	1,782
B: Hourly Charge	\$510

Estimated S61N Costs - Shuttle Service

Table 66

The unit transportation costs (\$ per one way shuttle passenger) over a range in annual demand from 25,000 to 300,000 person trips is shown in Figure 30. These costs apply equally to all three geographic areas under consideration.



Shuttle Helicopter Unit Transportation Cost
(0.25 Block Hour Shuttle Stages)

Figure 30

10.3.4 Dash-7 Shuttle Operating Costs

The fixed wing aircraft for the Stage 1 service was assumed to be based on shore. However, if required one aircraft could overnight on the floating STOLport. The operating costs for the Dash-7 aircraft were based on the cost information contained in Section 8. Person trip costs were calculated for the traffic range from 25,000 to 300,000 person trips annually for each of the three offshore locations being considered. The following cost and operating assumptions were made:

o Annual Standby Charge Per Aircraft	\$ 2,998,000
o Hourly Charge per Block Hour	630
o Load Factor	85%
o Maximum Operating Hours/Aircraft	2,500
o Minimum Round Trips Annually	260

The costs assumed that the aircraft would be dedicated to the service and no allowance was made for possible revenue generation from deploying the aircraft elsewhere.

The estimated unit operating costs for the three offshore systems are summarized in Table 67.

SYSTEM	SCOTIAN SHELF			HIBERNIA	LABRADOR SHELF	
BASE ANNUAL PASSENGERS X 1,000	HALIFAX (Base)	HALIFAX SYDNEY (Base)	HALIFAX SYDNEY YARMOUTH	ST. JOHNS (Base)	HOPEDALE (Base)	CART- WRIGHT (Base)
25	135	144	152	138	131	134
50	74	76	78	77	70	73
75	53	54	65	56	49	52
100	50	50	59	53	44	47
150	45	45	55	48	38	41
200	45	45	55	48	38	40
250	45	45	55	48	38	40
300	45	45	55	48	38	40

Dash-7 Operating Cost Dollars Per Passenger Trip

Table 67

10.3.5 STOLport System Cost Comparison

The STOLport alternatives examined fall into two categories; those such as the Seaforth Maritime Semi Submersible and the VLCC barge concepts which have no crude oil storage; and those such as the Seaforth Maritime STOLport Barge, and the VLCC STOLport Storage Barges which can store in the range of 1.75 million to 4.3 million barrels of crude. The crude storage concepts are particularly relevant to the Hibernia field, where it is anticipated that crude storage and transshipment facilities will have to be provided at the production sites in any case.

The capital cost of converting a 1.75 million barrel conventional VLCC to a storage function is estimated at \$25 million of which \$5 million is the estimated vessel purchase price, \$10 million the cost of the anchorage system and \$10 million the cost of vessel conversion and refitting. Assuming the same capital recovery factor and similar operating cost factors as were used for estimating the costs of the VLCC STOLport barge concepts, but excluding the airport-related STOLport crew costs, results in a total annual capital and operating cost of \$16.3 million per storage vessel (approximately \$9.30 per annum per barrel of crude oil storage capacity provided).

The STOLport cost comparisons were made under two assumptions:

- a) Gross costs, neglecting the benefit attributable to the crude oil storage capability offered by some alternatives;
- b) Net costs, allowing full credit at an annual rate of \$9.30 for each barrel of storage capacity provided.

Breakeven Traffic Volumes Based on Gross Costs

Gross systems costs were estimated for all STOLport concepts operating at the three geographic areas, and included vessel cost, Dash-7 operating costs and shuttle helicopter costs. The traffic volumes at which the upper and lower levels of base case costs equalled STOLport costs were identified for each alternative system. The break even traffic levels between the STOLport concepts and the assumed base case operations are illustrated in Figure 31 for the Hibernia Field. A similar analysis was performed for the other two areas. The upper and lower traffic breakpoints for the pure STOLports and the Seaforth STOLport Barge is shown on Table 68 for the three geographical areas.

Breakeven Traffic Levels - Net of Oil Storage Costs

The three concepts with crude oil storage capacities of 1.75 mm bbl, 3.5 mm bbl and 4.3 mm bbl respectively were evaluated on a net cost basis. This cost was arrived at by reducing the gross annual standby and operating costs for the relevant concepts by an amount equal to the estimated cost of providing equivalent storage separately, (estimated at an annual cost of \$9.30 per barrel storage annually). The resulting net STOLport system costs including Dash-7 and offshore based shuttle helicopter costs are shown on Figure 32 for a range of traffic demand. The traffic levels at which each alternate STOLport would provide the same cost of service on a unit person trip basis is shown in Table 69.

SYSTEM	BASE	VLCC BARGE* NO STORAGE		SEAFORTH STOLPORT BARGE		SEAFORTH SEMI- SUBMERSIBLE STOLPORT	
		UPPER BASE CASE COST	LOWER BASE CASE COST	UPPER BASE CASE COST	LOWER BASE CASE COST	UPPER BASE CASE COST	LOWER BASE CASE COST
Hibernia	St. John's	160,000	210,000	205,000	260,000	260,000	325,000
Scotian Shelf	Halifax	205,000	260,000	300,000	**	**	**
	Halifax/ Sydney	180,000	255,000	245,000	**	325,000	**
	Halifax/ Sydney/ Yarmouth	145,000	170,000	125,000	255,000	260,000	325,000
Labrador	Hopedale	**	**	**	**	**	**
	Cartwright	270,000	**	**	**	**	**

STOLport Comparison (Basis Gross Costs)

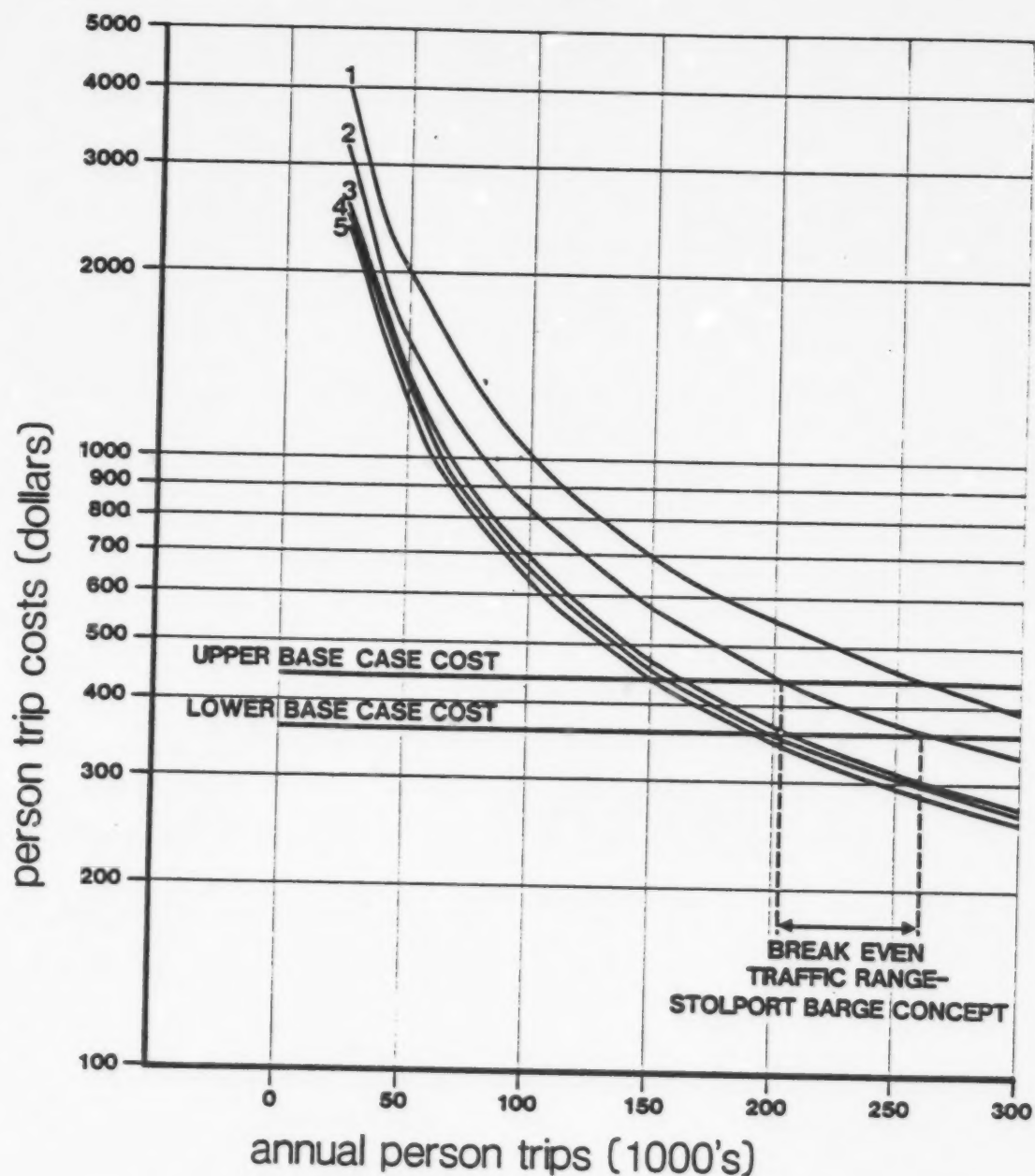
Table 68

** break points beyond upper level of study traffic range.

	BREAK EVEN POINT (PERSON TRIPS ANNUALLY)		
	1.75 mm bbl STORAGE	3.5 mm bbl STORAGE	4.3 mm bbl STORAGE
	VLCC BARGE	VLCC BARGE	SEAFORTH MARITIME STANDARD BARGE
Upper Base Case Cost	110,000	90,000	97,000
Lower Base Case Cost	137,000	120,000	125,000

Break Even Traffic Levels
STOLport Storage Barge Concepts

Table 69



- 1 SEAFORTH MARITIME SEMISUBMERSIBLE
- 2 SEAFORTH MARITIME STOLPORT BARGE
- 3 VLCC BARGE
- 4 VLCC BARGE 1.75mm bbl storage
- 5 VLCC BARGE 3.5mm bbl storage

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STOLPORT COST COMPARISON

Hibernia System

figure 31

10.4 Offshore Heliport Systems Cost Comparisons

10.4.1 Methodology

Two groups of offshore heliport systems were compared against base case operations. There were:

Group A - Operating System - In which the offshore heliports would be located near the centroid of offshore employment and employees would be transported to it from the shore base by a common helicopter service connecting with an offshore short haul helicopter shuttle operating between the heliport and the individual production platforms.

Group B - Operating System - In which an offshore heliport would be designed to meet Transport Canada Standards for an IFR alternate facility and would be used as an intermediate landing facility by helicopters flying directly from shore based facilities to the offshore production platforms.

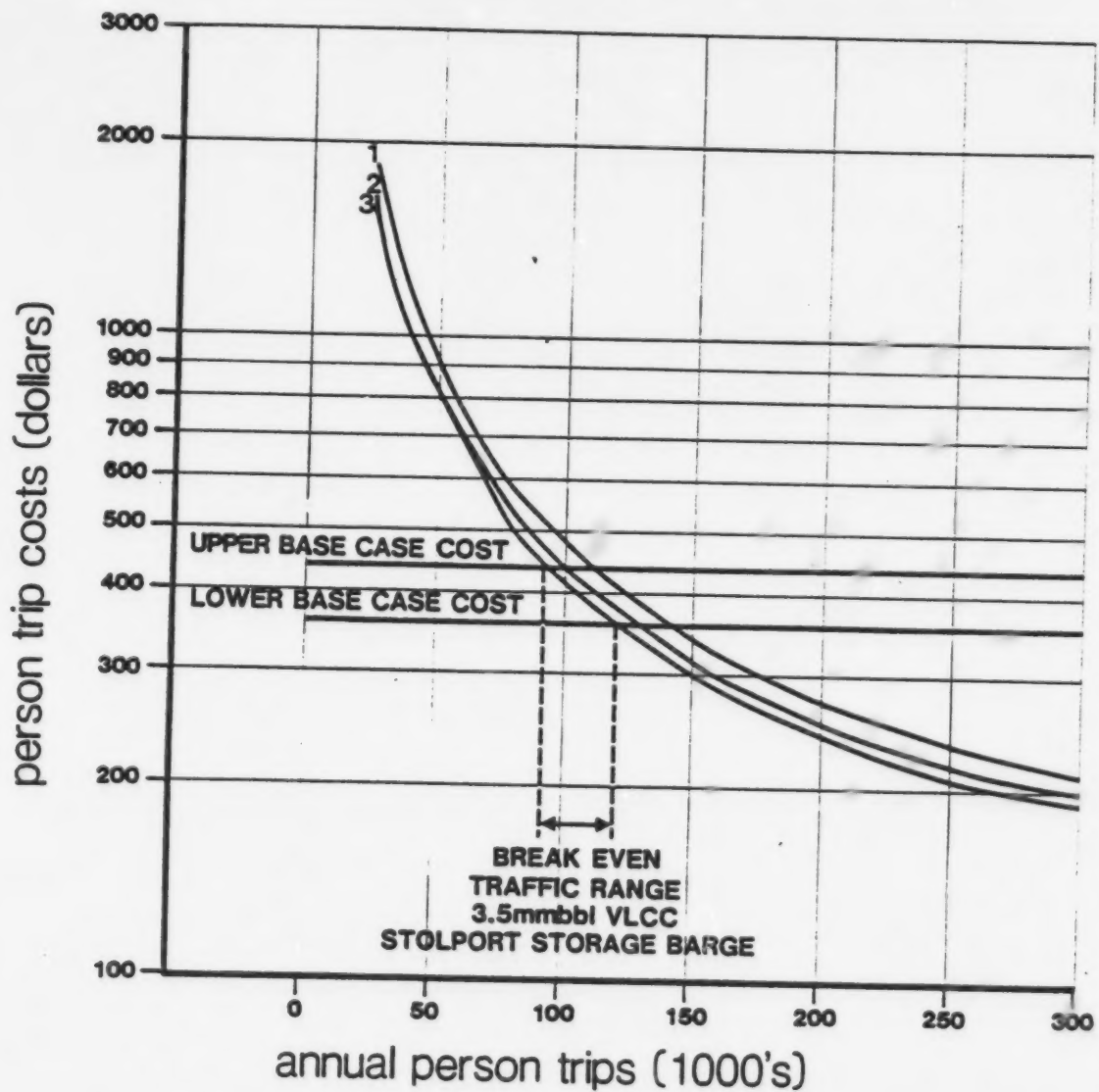
10.4.2 Level of Service Assumptions

The level of service assumptions applicable to System A are the same as those assumed for the floating STOLport alternatives. The Stage 1 or primary helicopter shuttle would operate on a minimum of 260 days annually with average assumed load factors of 85 percent. Flying times were based on still air conditions and no allowance was made for weather related delays.

The offshore based secondary or Stage 2 shuttle was assumed to operate in the same manner as that assumed in the floating STOLport systems evaluation.

10.4.3 Base Case Operating Costs

The base case operating costs were the same as those assumed for the STOLport systems evaluation.



- 1 VLCC STOLPORT BARGE (1.75mmbbbl storage)
- 2 SEAFORTH MARITIME STOLPORT BARGE (4.3mmbbbl storage)
- 3 VLCC STOLPORT BARGE (3.5mmbbbl storage)

IBI Group

STOLPORT STORAGE BARGES net systems cost comparisons

figure 32

10.4.4 Offshore Shuttle Helicopter Operating Costs

The Stage 2 operating costs were assumed to be identical to those assumed in the STOLport systems evaluation.

10.4.5 Evaluation of Group A Operating Systems

The principle potential benefit of this operating system was a possible reduction in operating costs through more effective helicopter utilization through common useage on the primary or Stage 1 service.

Secondary benefits could include improved service reliability resulting from the opportunity to install more comprehensive and more effective navigation and landing aids at an unobstructed centralized facility.

Offsetting disbenefits include the costs of providing the Stage 2 offshore shuttle and the increased travel time resulting from the passenger transfer time between the Stage 1 and Stage 2 helicopter services.

For the Hibernia System, the total cost for the operating system could be as high as \$1,280 per person trip. The corresponding base costs estimates were in the range of \$367 to \$439 per person trip. The system would be less economical for the Scotia and Labrador Sea Systems because they involve shorter operating primary stages. The exception would be the case of the tri based service including Halifax, Sydney and Yarmouth where a shuttle serving a group of rigs in the Sable Island zone would result in better equipment utilization than would the base case service. Even in this situation the break even traffic levels would be relatively high when compared with likely demand.

If it were possible to convert a surplus semi-submersible drilling or production platform to a heliport at a capital cost in the order of say \$10 million, the transportation costs on a person trip basis would be

reduced to between \$869 (25,000 annual trips) to \$350 (300,000 annual trips). The break even point could then be lowered to the level of between 125,000 to 270,000 total person trips annually for the Hibernia case. However this would be a special situation depending upon platform availability and ease of refit. Also, for the system to be economic on an overall basis, the delays arising from personnel transfer between the two trip stages would have to be substantially offset by improvements in service reliability resulting from improved landing aids implicit in this concept.

10.4.6 Evaluation of Group B Operating System

Operating System B assumes that an offshore heliport could be built and equipped to the standards necessary for licensing as an IFR alternate by Transport Canada. Official standards pertaining to such facilities do not currently exist but, the underlying assumption in the analysis was that a facility could be constructed to the required future standards for the capital costs outlined in Table 55.

The principle benefit of this alternative is that with an IFR alternate heliport strategically located offshore, the payload/range of helicopters could be significantly improved and this would allow more effective utilization of short range helicopters having lower operating costs.

Table 70 shows the break even traffic levels for a range of helicopters types assuming an optimally located offshore IFR alternate heliport and operating radii ranging from 150 to 300 nm.

A IFR alternate heliport optimally located for a 300 nm operating radius, could reduce costs by approximately 35%, or by a about \$140 per person trip from the base case costs.

HELIPORT ALTERNATIVE	APPROXIMATE BREAKEVEN LEVEL ANNUAL PERSON TRIPS (1000's)
Artificial Island	703
Virgin Rocks	152
VLCC	127
Tension Leg Structure	184
Semi-submersible (new)	140
Semi-submersible (conversion)	72

Breakeven Traffic Levels Offshore IFR Alternate Heliport Table 70

10.5 Comparison of SWATH Vessel & Offshore Helicopter Shuttle Costs

The principle advantage perceived for the SWATH personnel carrier over offshore based helicopters is the ability of the former to operate during IFR Category III weather conditions when helicopter services to the platforms would probably be inoperable. The annual capital and operating costs for a SWATH vessel are estimated at approximately \$8.3 million annually. The breakeven traffic level between a SWATH service and a shuttle helicopter service would be of the order of 150,000 annual person trips.

The major benefit attributable to the SWATH vessel would be potential savings due to elimination of weather related delays. In the Hibernia field, approximately 13% of the trips by air could be delayed by adverse flying weather. Assuming these delays could be reduced to 5% by the introduction of a Category III operation for the primary shuttle, the break point for the Secondary service by SWATH vessel could be lowered to approximately 100,000 annual person trips.

10.6 Impact of Aviation System Delays

Three categories of potential aviation system delays were analyzed, there being those due to:

- o wind conditions;
- o poor visibility;
- o passenger transfer time between modes.

10.6.1 Effect of Wind on STOLport Availability

The Dash-7 demonstrated crosswind landing capability under VFR exceeds 30 knots. While it has not been definitely established, indications, are that Transport Canada regulations may limit landings to crosswind conditions of less than 20 knots during IFR Category II conditions. Under normal conditions, the STOLport runway would be aligned with the wind so that as a general rule crosswinds should not be a serious problem. However, under some heavy sea conditions, where wind and wave directions are sufficiently out of phase, high crosswinds could close down airport operations.

Statistics directly co-relating wave and wind direction were not available. However comparison of separate wind and wave direction frequency charts indicated that there is a high probability that under VFR conditions the runway could usually be so orientated as to keep crosswinds below the 30 knot crosswind component limit at all three locations.

The 20 knot crosswind component limitation under IFR conditions causes greater concern since less statistical information is available on wind and bad weather correlation. However, there appears to be a strong link between low wind speeds and poor visibility. During the bad weather summer months the wind speeds at the 95% upper level are below 30 knots. These lower winds would normally be accompanied by reduced sea states thereby allowing greater vessel manoeuvrability and closer runway alignment with the wind.

Therefore, while crosswinds do not appear to be a severely limiting factor, further investigations are necessary to confirm this opinion.

10.6.2 Effect of Wind on Aircraft Flying Times

All three geographical areas experience a high incidence of strong winds. In all three systems the prevailing winds are westerly so that flying times on outbound legs would be reduced to below average and those on inbound legs increased. The exception is for flights from Cartwright in the Labrador Sea system, where strong northerly winds would impede outbound flights. Because helicopters fly at slower speeds, their performance would be more effected by winds, than would that of the Dash-7.

The available wind data does not allow precise estimates of wind related delays. However, the following table indicates the likely upper impact at the 5th and 10th percentile delay levels.

SYSTEM	AIRCRAFT		FLYING TIME (minutes)*	
			5th PERCENTILE	10th PERCENTILE
Scotian (still air 88 min stage)	S61N	Max.	130	160
		Min.	75	82
		Average	102	96
Hibernia (still air 98 min stage)	AS332L	Max.	136	115
		Min.	81	86
		Average	108	100
Hibernia (still air 67 min stage)	Dash-7	Max.	79	74
		Min.	58	61
		Average	69	68

Effect of Wind Conditions on Helicopter Performance

Table 71

* Includes IFR manoeuvring time of 7 minutes

The effect of wind would be to increase S61N annual operating costs by approximately 4% over still air costs, AS332L costs by approximately 2% and Dash-7 costs by less than 1%.

10.6.3 Visibility Related Delays

In addition to wind conditions, the other aviation weather related delay factor is inadequate ceiling and/or horizontal visibility to achieve safe landings. As described in Sections 2 and 3, the format of the available weather data did not permit a detailed assessment of visibility conditions for aviation purposes. Assuming Category II operations; ceiling above 30m and horizontal visibility greater than 400m, weather related delays can be anticipated at all three locations and particularly during the summer months at Hibernia (13%).

An important factor in assessing potential visibility related aviation delays is the frequency distribution of break periods or windows during which the weather is within limits. For example, on offshore-based helicopter shuttle operation, because of the short flying distances involved, could effectively take advantage of weather windows as short as one hour or even less. A helicopter on a long stage length however, might require that there be reasonable probability of a three hour window being available before it departs. Table 72 shows the frequency of occurrence of windows of 1, 2, 3, 6 and 8 hours continuous duration for each area. This latter information is based on a highly judgemental assessment but serves to illustrate the likely magnitude of the problem. The window lengths were selected on the basis of the following service assumptions:

<u>Time</u>	<u>Type of Operations Feasible</u>
1 hour -	offshore shuttle, helicopter operation only;
2 hours -	low volume, Dash-7 service;
3 hours -	low volume, helicopter service;
6 hours -	intermediate volume Dash-7 service high volume helicopter service;
8 hours -	high volume Dash-7 service.

WEATHER WINDOW* DURATION (Hours)	SCOTIAN SYSTEM	HIBERNIA SYSTEM	LABRADOR SEA SYSTEM	
			12 MONTH PERIOD	JUNE TO NOV.
1	4(10)**	12(15+)	4(10)	2(2)
2	5(10)	12(15+)	4(10)	2(2)
3	5(10)	13+(15+)	5(10)	2(3)
6	7(10)	13+(15+)	7(15)	4(10)
8	10(10)	13+(15+)	7(15)	5(10)

Estimated Percentage of Annual Weather Falling Below IFR Category 2 Minima Daylight Period

Table 72

- * Continuous period during which weather remains above Category 2 minima.
 ** Worst monthly percentage in brackets.

The average cost of delay (dollars per person trip) is by the following table assuming platform size of 100 employees:

<u>Item</u>	<u>Daily Cost</u>
Overtime pay specialists - 30 men @ \$400/day =	\$12,000
Overtime other personnel 70 men @ \$100/day =	7,000
Accommodation and food at land base @ \$100.day =	<u>12,000</u>
Total	\$31,000
Cost penalty per delayed person trip:	\$155/day

The estimated annual employee delay costs resulting from the unavailability of weather windows necessary to accommodate Dash-7 requirements are shown in Table 73 (helicopter weather related delays would be marginally higher):

TRAFFIC DEMAND 1000's OF PERSON TRIPS	SCOTIAN SHELF	HIBERNIA	LABRADOR SEA	
			12 MONTH SEASON	6 MONTH SEASON
25,000	194	465	155	39
50,000	348	930	310	78
75,000	545	14,720	496	117
100,000	744	1,937	697	170
150,000	1,255	2,945	1,290	263
200,000	1,767	3,937	1,674	449
250,000	2,433	4,960	2,170	601
300,000	2,939	5,997	2,604	720

Annual Cost of Employee Delay
(\$1000's Cdn.)

Table 73

10.6.4 Passenger Transfer Time Losses Between Modes

The floating STOLport options and those floating heliport options which, envisage a two stage passenger transportation system involve a time loss to cover passenger transfer between the long haul shuttle aircraft and the short haul offshore based helicopter shuttle.

where the transfer occurs between a long haul and a short haul helicopter, the entire transfer time, estimated at 30 minutes minimum, represents a time penalty against the system. Offsetting this cost the potential improvement in service reliability attributable to improved landing aids which could be provided at a centralized facility but possibly not at individual production platforms.

For Dash-7 operations at both the Hibernia and Scotian Systems, the intermodal transfer time penalty of approximately 30 minutes would offset by the speed advantage of the Dash-7 over helicopters as shown below:

Scotian System

S-61N flying time	95 minutes
Dash-7 flying time	<u>54 minutes</u>
Time saving	41 minutes*

Hibernia System

AS332L flying time	98 minutes
Dash-7 flying time	<u>67 minutes</u>
Time saving	31 minutes*

* Figures allow for differential helicopter operating speeds.

For the Labrador Sea case, there would be a net penalty of approximately 15 minutes because short stage lengths involved are too short to generate adequate time savings to offset the passenger transfer times.

The passenger transfer times between modes at the floating STOLport or heliport with the SWATH vessel concept could require several hours because it would be necessary to concentrate passengers from several inbound flights to produce economic SWATH vessel loads. Similarly a number of departing flights would be necessary to clear traffic from a single SWATH vessel arrival at an offshore airport/heliport. The advantage of the SWATH vessel, in the context of delay, is that if Category III operations were possible for the Stage 1 aviation service, a very considerable portion of the residual weather related uncertainties and delays associated with the Stage 2 helicopter shuttle service could be eliminated, a major benefit particularly at the Hibernia Site.

10.7 Economic Evaluation

Economic Setting

To set the economic context for this study two quotations are offered from a study by Roger Voyer, published by The Canadian Institute for

Economic Policy, entitled Offshore Oil - Opportunities for Industrial Development and Job Creation.²⁹

"Venture and Hibernia are two commercially viable finds, one gas and the other oil..."

"The cost of developing the Venture/Sable Island gas field is estimated to be about \$3 billion and the Hibernia field from between \$3.5 billion to \$9 billion:"

The capital cost of the physical facilities examined in the current study ranges between \$46 million and \$475 million excluding the cost of rotary wing and STOL aircraft.

Based on the "most likely" forecast of offshore employment, investment in rotary wing aircraft could range between \$28 million to \$37 million for the Hibernia field and \$18 million to \$28 million for the Sable Island field.

The estimated annual base cost for employee transfer to the Hibernia field assuming 150 man platforms and 2 week rotation, was \$38 million, or approximately 13% of the total estimated annual operating expenses (1981) for a single semi-submersible production platform. Allowing for the costs of delays, extra flights transfer of goods could increase this figure to 16%.

Canadian Ship Building Capability

The capability of the Canadian ship building industry to construct the floating airport facilities examined in the study must be viewed in the

²⁹ Voyer, Royer, Offshore Oil Opportunities for Industrial Development and Job Creation. Canadian Institute for Economic Policy. Ottawa, '85

context of its recent past performances. The Canadian Institute for Economic Policy Study referred to previously made the following pertinent points:

"Canada's ability to sell ships is also limited by the ready availability of cost subsidies and concessionary financing abroad"

"A major constraint limiting the degree to which the Canadian industry will obtain new business relates to its capacity."

The first point is illustrated by the hourly compensation in selected world ship building industries (1980):

COUNTRY	HOURLY COMPENSATION (\$ U.S.)
United States	11.94
Canada	10.76
Japan	7.48
Korea	1.74
Norway	10.93*
U.K.	5.45*

Compensation Rates Selected Shipbuilding Industries³⁰

Table 74

* 1979 Figures

The capability of Canada to produce vessels of the types researched in this study should be considered in the context of the following statistics for 1980:

Total Canadian Industry output was \$1 billion of which \$522 million represented new construction. Total industry employment was 17,000 persons. The total output for Atlantic Canada was \$249 million. Industry employment was 5,000 persons.

³⁰ U.S. Department of Commerce, Bureau of Labor Statistics, February, 1981. Unpublished Statistics.

International Labor Office, Yearbook of Labor Statistics, Geneva, 1981.

The least cost STOLport concept, the VLCC Barge (Canadian construction) was estimated at \$325 million and the highest cost concept, the Seaforth Maritime semi-submersible concept was estimated at \$472 million. Clearly construction of any of the proposed concepts in Canada, even if the work were spread over a 3-4 year period, would make a substantial contribution to the local shipbuilding industry. On the other hand it would severely tax available capability, if not overtax it.

An indication of the potential labour content of the proposed marine facilities can be obtained from the following table.

COMPONENT COST OF SEMI-SUBMERSIBLE STORAGE VESSELS	ESTIMATED COST (1981 \$ millions)	%
Diesel engines	12.0	4
Shafts and propellers	3.0	1
Steel	60.0	20
Miscellaneous direct charges and equipment	90.0	30
Labour and overhead	135.0	45
Total	300.0	100

Component Cost of Semi-Submersible Storage Vessels

Table 75

A comparable estimate made by the Norwegian Ship Institute for the Seaforth Maritime Semi-submersible STOLport had the following breakdown.

COMPONENT (Including Labour*)	ESTIMATED COST 1981 NOK Millions	%
Steel	1837.7	74
Diesel Engines	94.3	4
Thrusters	67.9	3
Cabins	37.0	1
Piping	444.5	1.8
Total	2486.3	100

Component Cost Comparison

Table 76

* Labour input estimated at 85 man hours per ton.

Both estimates indicate high level of steel and labour components, both of which are in good to fair supply in Canada. The major factors potentially inhibiting the supply of the floating marine facilities forming the subject of this report are the lack of a suitable dry dock and supporting infrastructure and non-competitive labour rates.

Aviation Equipment Considerations

The offshore aviation field is dominated by helicopters which are principally manufactured in the U.S. with the notable exception of the Super Puma (AS332L) which is manufactured by Aerospatiale in France. There are some opportunities for Canadian manufacturers in the manufacture of avionics equipment and specialized equipment such as ice detection systems, but apart from this, the main opportunity appears to lie in the area of sub-contracting component construction. The combined foreign expenditures for helicopters in the Scotian and Hibernia fields are estimated at between \$46 million and \$65 million over the intermediate term.

A major objective of this study was to examine the potential for utilizing Dash-7 aircraft for offshore transportation. Provided that any of the floating STOLport concepts studied were to materialize, a potential sale of aircraft and parts in the order of \$22 million in each of the Hibernia and Sable Island fields would result. Apart from some specialized components, the majority of this expenditure would be made in Canada. There is also potential for Dash-7 sales to serve the regional aviation system supporting the shore bases particularly those in the Labrador Sea area.

Comparison of Concepts

The most viable heliport concept appears to be a semi-submersible drilling rig converted to serve as an IFR alternate heliport. Conversion costs could be of the order of \$20 million and this work could

probably be carried out in Canada. Some of the navalds and landing aids, estimated at \$4.3 million per facility could be built in Canada but a substantial part of this equipment would be foreign purchase. Electronic equipment installation costs, estimated at approximately 10% of the total would be largely Canadian sourced.

The floating STOLport barge concepts offer the best opportunity for Canadian content. Estimates detailed in this study indicate for example, that the VLCC Barge could be constructed in Canada at a premium of \$52 million largely attributable to temporary drydock construction.

The potential for Dash-7 aircraft sales is primarily linked to the economic viability of the floating STOLport concept but there are potential sales to regional carriers, possible under all concepts.

The viability of the Seaforth semi-submersible STOLport concept over the range of traffic forecasts developed for this study is heavily dependant upon the need for floatel type accommodation to house offshore construction workers. Such a requirement was not identified as being required by the oil companies supporting this study.

The economic viability of the STOLport barge concepts is heavily dependent upon opportunities for offsetting some of their operating costs against their crude oil storage capability. An indication of the significance of cost sharing is indicated by the fact that the Seaforth Maritime STOLport Barge with 4.3 mm bbl crude oil storage capacity is estimated to cost \$375 million while a semi-submersible storage vessel alone for the Hibernia field could cost \$300 million.

The potential for technology export lies primarily with the sale of Dash-7 aircraft since it is unlikely that the Canadian shipbuilding industry would be competitive in the export market.

11.0 SENSITIVITY AND RISK CONSIDERATIONS

11.1 Scope

This research project was undertaken to provide comprehensive insights into the scope for innovative solutions in air transportation systems to support the expanding petroleum industry off Canada's east coast. Because of the adverse marine and atmospheric environmental conditions which prevail in the study area, emphasis was placed on the analysis of these problems to ensure that the physical and operating systems selected for evaluation were technically feasible and viable.

On the marine side, computerized experimental simulation models were used to assess the safety and operational practicability of the proposed marine structures and vessels. On the aviation side, the study examined both the extension of current land based practices to offshore locations, as well as the potential for full extension of state-of-the-art technology to achieve fully or near fully automatic landings by both helicopters and STOL aircraft on floating platforms.

There were a number of areas where existing information was inadequate or unavailable, and where development of an improved data base was not feasible within the time and resource constraints of the study. For example, the oilfield logistics and related staffing requirements are based on relatively limited direct geological information; some of the solutions involve vessels of a type and size which have never been built; employment standards, pay scales, government policy and involvement and operating jurisdiction are all areas of uncertainty in which many judgements were made.

Throughout the study reference has been made to the assumptions and judgements underlying specific aspects of the analyses. In order to form an understanding of how dependent the final results are on selected judgementally arrived at values, a sensitivity analysis was conducted.

Assumptions were also made regarding the location of the early offshore development areas, the likely airports and supply bases to be used, the rate of increase of offshore employment, and the practicability of developing advanced technological solutions within acceptable time frames. The impact of these factors was assessed by risk analysis techniques.

11.2 Sensitivity Analysis

The main criterion by which the alternative systems were compared was the annual traffic level (one way person trips) at which the cost per person trip for each operating system equalled that of the Base Case for the same service.

The sensitivity analysis consisted of calculating the change in "break even" traffic level corresponding to finite increases and decreases in the values of the selected critical cost related variables.

In order to restrict calculations to reasonable levels, the sensitivity analysis was confined to the Hibernia system. It was selected because it was the only one of the three systems for which the entire range of proposed physical solutions had possible application.

The cost related variables selected for analysis were the following:

Variable	Range* %
Capital Cost of Floating STOLports	+ 20
Operating Cost of Floating STOLports	+ 20
Base Case Helicopter Operating Costs	+ 10
Capital Cost of Heliports	+ 20
Operating Cost of Offshore Heliports	+ 20
Annual Cost of Crude Oil Storage	+ 20

* Selected to be consistent with likely range of error in the underlying assumptions.

It is important to note that the capital costs for this VLCC barge concepts assume the availability of five suitable surplus VLCC vessels at reasonable cost. Failing this, their costs could approach or even exceed the cost estimated for the all new Seaforth Maritime STOLport barge.

11.2.1 Effect of Variations In STOLport Capital and Operating Costs

The sensitivity analysis examines three factors:

- o range in capital recovery factor
- o range in capital cost
- o range in operating cost.

Capital Recovery Factor

The practical range in annual capital recovery factor is as follows:

Interest Rate %	Capital Recovery Period Years		
%	12	15	20
10	.147	.151	.117
12	.161	.146*	.134
15	.191	.174	.161

Annual Capital Recovery Factor Range

Table 77

* CRF Assumed in study.

A 12 year life for the vessel, rather than the assumed 15 year life would increase annual capital costs by approximately 10 percent and a 20 year life would decrease costs by 8%. Decreasing the assumed interest rate from 12 percent to 10 percent would decrease annual capital costs by 10%. A 15 percent interest rate would increase annual capital costs by 19%.

Capital Costs

Three estimates were prepared for the Seaforth Maritime Semi-submersible floating STOLport in 1981. These were 1200 million Norwegian Krone, NOK 2000 million, and NOK 2486 million. Escalating these figures by 14 percent to allow for inflation and converting at the current exchange rate results in costs of \$228 million, \$380 million and \$472 million respectively. The costs show a variation of +31 percent, -58 percent from the mean cost of \$380 million.

The current study assumes the upper capital cost of \$472 million, a value which was selected to include the cost of towing the vessel from drydock to its operating location. The selection of the cost was somewhat arbitrary in that the actual location of the construction site was not identified but it was felt that the possibly lower construction costs at far eastern dry docks would at least be partially offset by higher towing costs.

For sensitivity analysis purposes, a capital cost variation of ± 20 percent was used. This corresponds to capital costs ranging from \$578 million to \$566 million.

The capital costs of the other STOLport alternatives were calculated as part of this study. They are believed to be conservative but again there is no directly applicable experience against which to confirm them. In the case of the VLCC barges, their construction practicability and cost are highly dependent upon the availability of a number of surplus matching VLCC tankers. In the absence of such vessels, the costs would rise towards those estimated for the Seaforth Maritime STOLport Barge concept. The 20 percent variation assumed for the semi-submersible concept was therefore applied equally to all alternatives evaluated.

Operating Costs STOLport

Operating costs in the context of the sensitivity analysis include all costs other than capital costs. An arbitrary variation of ± 20 percent was assumed.

Operating Costs - Base Case Helicopters

The helicopter operating costs are based on current experience and are believed to be reasonably reliable. However, since there is some scope for economy of scale and since no allowance was made for delay costs, a variation of ± 10 percent was felt to be reasonable.

Dash-7 and Offshore Helicopter Shuttle Operating Costs

For most systems these costs, form a relatively small part of the total operating costs. Thus variations of up to ± 20 percent would not significantly affect total STOLport system operating costs in the critical trade off range. This effect was therefore ignored.

Summary

The effects of the operating and capital cost variations on the system breakeven points are summarized in Table 78. For no case did the relative ranking of the alternatives change over the range of assumed values. If advantage could be taken in practice of the crude oil storage capability of the STOLport barge concepts, a reduction of 20 percent in assumed capital costs for the hybrid STOLport barges could result in their being economically viable at the lower levels of the current forecasts. A similar situation would result for some other concepts if the Base Case costs prove to be underestimated by as little as 10 percent.

FLOATING STOLPORT ALTERNATIVE	BREAK EVEN POINTS - ANNUAL PERSON TRIPS (1,000'S)						
	Base Case Orig. Cost	Variation In Capital Cost		Variation In Operating Cost		Variation In Base Cost	
		+ 20%	-20%	+ 20%	- 20%	+ 10%	- 10%
Seaforth Maritime Semi-Submersible	291	334	215	307	276	233	333
Seaforth Maritime Barge	231	265	196	243	219	185	264
VLCC Barge	166	188	143	176	153	133	189
Seaforth Maritime Barge* 4.3 nm bbl crude oil stg.	110**	140	77	117	98	98	121
VLCC Barge* 1.75 nm bbl crude oil stg.	121	142	101	131	110	111	138
VLCC Barge* 3.5 nm bbl crude oil stg.	86	110	67	93	75	68	98

Sensitivity Chart

Effect of Capital and Operating Cost Variations
On Hibernia System Break Even Traffic

Table 78

* Based on Capital and Operating Costs Net of Credits for Crude Oil Storage

** The Seaforth Maritime Barge, with only 1.75 nm bbl useable crude oil storage would break even at 177,000 annual person trips and with 3.5 nm bbl useable storage at 129,000 annual person trips.

11.2.2 Effect of Variations In Crude Oil Storage Costs

The annual cost of storing crude oil in modified tankers anchored at the production site was calculated at \$9.30 per barrel. For those concepts which combined STOLport facilities with crude oil storage facilities, the cost attributed to the STOLport operation was the total cost net of the assumed benefit gained from oil storage at the \$9.30 per barrel rate. The sensitivity of the STOLport costs to variations in the cost of crude oil storage was tested by assuming a $\pm$ 20 percent variation in the value of the storage provided (maximum cost of \$14.00, minimum cost of \$7.50 per barrel of capacity). The resulting break even points are shown in Table 79.

CONCEPT	CRUDE STORAGE COSTS		
	\$7.50	\$9.30	\$11.00
Seaforth Maritime STOLport barge (4.3 mm bbl Storage)	130	110	91
VLCC STOLport Barge (1.75 mm bbl Storage)	130	121	111
VLCC Storage Barge (3.5 mm bbl Storage)	102	86	64

Hibernia Field Breakeven Traffic Level
STOLport Barge Capacity
Person Trips Per Annum (1000's)

Table 79

11.2.3 Effects of Increased Stage Length

The stage length or distance to the Hibernia zone varies between 154 to 254 nm (50 nm radius about a 204 nm centroid). Over this range the Super Puma helicopter has an average theoretical payload of 19 and the Chinook, 44. If the centroid of the development zone were to be located 50 nm further to the east, the average effective payload for the two helicopters would drop to 16 and 34 passengers respectively. The combined effect of the reduced payloads and the extra flying time would increase optimized helicopter operating costs by approximately 50%. If the base costs rose in a similar proportion as optimized shuttle costs, the effect of increasing stage lengths by 50nm would reduce the break point traffic levels for all concepts studied to the levels shown in Table 80.

STOLPORT ALTERNATIVE	OPERATING RADIUS	
	204 nm*	250 nm
Seaforth Maritime Semi-Submersible	291	180
Seaforth Maritime STOL Barge	231	142
VLCC Barge	166	105
Seaforth Maritime Barge (Net)	125	81
VLCC [-3.75 mm bbl Storage] (Net)	121	78
VLCC [-3.5 mm bbl Storage] (Net)	90	57

Break Even Traffic Levels
Annual Person Trips (1000's)

Table 80

* Hibernia operating radius assumed in study.

11.3 Risk Analysis STOLports

11.3.1 Effect of Price Escalation

The cost evaluations in this study were based on 1983 capital and operating costs assuming a 12 percent current rate of interest. Operating costs were kept constant in 1983 dollars. The interest value, is based on an inflation rate of 9 percent and a real rate of return of 3 percent. The costing assumptions imply investment at a fixed interest rate at the beginning of the period and constant unit operating costs at 1983 prices, that is, no price escalation. Current interest rates are commonly used for private sector investment decisions and usually include estimates of price escalation factors for labour and material. An alternative method, more often used by government, is to carry out the assessment assuming constant dollars and real rates of interest.

The breakeven points assuming a 12 year capital recovery period and a real rate of return of 3 percent are as follows:

Concept	12% Interest No Price Escalation	3% Real Rate of Return: (Constant 1983 Dollars)
Seaforth Maritime Semi-Submersible	291	202
Seaforth Maritime STOLport Barge	231	158
VLCC Barge	166	117

Breakeven Traffic Levels
Annual Person Trips (1000's)

Table 81

11.3.2 Impact of Floatel Requirements

The North Sea experience indicates a need for offshore construction barges or floatels housing up to 500 persons. Because of the high

level of activity in such fields as Shetland and Ekofisk such platforms are in service on a more or less continuous basis. These extra activities place an additional load on the transportation system, but they also provide opportunities for facilities sharing. The Seaforth Maritime semi-submersible concept has as one of its options, the provision of floatel facilities. The estimated cost of a 450 bed units was of the order of \$5-\$7 million and total annual cost including catering was (1985) NOK 222 million (\$37 million Cdn.).

The break even points for the STOLport with various levels of floatel accommodation, assuming S61N helicopter costs, for the Norwegian sector were as follows:

STOLPORT ESTIMATE	Approximate Breakeven Traffic Level 1000's of Two-Way Person Trips		
	With 800 Bed Floatel	With 450 Bed Floatel	No Floatel
High Cost	180	230	255
Average Cost	110	165	190
Low Cost	80	100	145

Impact of Floatel Requirements

Table 82

If a need for floatel facilities were to materialize off Canada's east coast, significant economies might be achieved by combining STOLport and floatel facilities along the lines proposed by Seaforth Maritime for North Sea operations.

11.3.3 Effect of the Length of Operating Season

The evaluation for all three zones assumes a 12 month operating period. For most of the physical systems proposed this would not be practical

In the Labrador Sea. Shutdowns for extended periods might also prove necessary at the other two locations. Since the Labrador Sea costs would be the most effected by downtime an assessment was made of the impact on annual costs of a 6 month shutdown.

This summary indicates that for the range of options studied, those concepts having high capital costs run a greater risk of incurring high annual total operating costs due to shutdowns than do those with lower capital costs and higher operating costs.

OPTION (Assumes Hopedale Operating Base)	PERCENT INCREASE IN PERSON TRIP COSTS
Base Case Costs (Helicopter Operations)	32
VLCC STOLport Cost	73
Seaforth STOLport Barge with Storage	91
VLCC STOLport with 1.75mm bbl	87
VLCC Helipport (System A operation)	42
Dash-7 Operating Costs	45

Effect of Six Month Reduction in Operating Season

Table 83

11.3.4 Effect of the Construction of a Sable Island STOLport

The construction of a STOLport on Sable Island to service part of the Scotian System has been advocated by a number interested parties.

The capital cost of a STOLport at this location is highly dependent upon its specific siting. The area near the present Interim landing site on the beach appears subject to erosion by wave action with problems due to drifting sand. Higher points of land offer better

potential but airport construction at such locations would necessitate removal of tenuous vegetation, which could result in serious wind erosion and eventual interference with the habitat of the pony population. Indications are that a STOL airport could be constructed in a manner which would be compatible with the environment, particularly if higher maintenance costs were acceptable.

The capital costs of a STOLport facility, including feasibility studies, design and construction of a 800m x 30m runway, three Dash-7 parking positions, a heliport, a combined Dash-7/helicopter hangar, an operations building, a 100 bed hostel, Navaids, visual aids and landing aids, utilities, support facilities and equipment would be in the order of \$20 million, excluding major marine protective works. The combined operating cost for the airport facilities including the hostel, but excluding catering costs for the hostel is estimated at \$9.2 million annually assuming a two shift operation.

The breakeven traffic level for the Scotian system for the VLCC barge, the least expensive alternative (if the benefits of crude oil storage are not included) is 230,000 annual person trips, at an average cost of approximately \$310 per trip and for a Sable Island-based STOLport, approximately 55,000 person trips. This latter figure excludes any secondary benefits arising from the airport. It is clear, therefore, that the decision regarding a STOLport on Sable Island should be resolved prior to considering the development of more costly floating STOLport or heliport alternatives for this zone.

12.0 DEVELOPMENT IMPLICATIONS

12.1 Overview

Transfer of personnel by helicopter between supply bases on Canada's east coast and offshore drilling platforms involves high operating costs, passenger inconvenience and unpredictable service due to adverse weather conditions.

Operating costs which are already high are expected to increase as traffic grows and as exploration and production moves to more remote locations.

Improved air navigation and landing aids and more comprehensive meteorological services will result in some improvements in service, but reductions in landing minima are likely to continue to be limited by the airspace constraints at the platform based helipads.

Passenger convenience will improve as larger, safer, and more comfortable helicopters are introduced into service. Speeds are likely to remain relatively low and the incidence of weather related delays will remain high. The effect of these two latter factors will become more pronounced as flying distances increase.

The study showed that many of the current problems could be improved by improved helicopter technology and support services, however; the greatest potential for improvement lies with introduction of fixed wing STOL aircraft operating from land to offshore floating airports. A number of such concepts were examined, and while all appeared to be technically feasible, their high capital costs offset the potential cost savings resulting from reduced aircraft operating costs. With some of the concepts, the deficits were at near manageable levels and as a result there is a strong possibility that one or more of them may prove feasible if the actual traffic volumes surpass forecast levels.

Tilt wing/rotor concepts were also examined. Such aircraft have the advantage of the higher en route speeds associated with fixed wing aircraft and the vertical takeoff and landing capability of helicopters. Aircraft of this type are currently being tested by the U.S. military, but considerable work will be required to establish their viability in civilian applications. Preliminary indications are that the operating costs of such aircraft will be significantly higher than those for the Dash-7, but considerably lower than those for helicopters of equivalent size. Their landing capability under adverse weather conditions similar to those prevailing in parts of the study area are not likely to be superior to that of conventional helicopters. While the aircraft appear to have certain advantages over both helicopters and fixed wing aircraft in the applications under study, no definite conclusions can be drawn at this time.

The effectiveness of semi-submersible catamaran type passenger vessels was also studied but in less detail since they are marine vessels and do not lie completely within the scope of this study. These vessels, which are now entering service, have good operating characteristics in heavy seas, and can serve either as a primary or secondary transport mode depending upon the travel distances involved. Within the context of this study they were examined as a possible alternative to offshore based helicopters providing a service link from a floating STOLport to the production platforms.

12.2 Primary Systems Findings

12.2.1 Semi-Submersible STOLports

The Seaforth Maritime semi-submersible STOLport and represents a technically feasible concept to accommodate STOL aircraft operations off the east coast of Canada. It is a highly innovative concept and illustrates some of the most advanced thinking in the aviation field. Apart

from providing a secure runway for fixed wing aircraft, the vessel could also provide offshore living accommodations for construction workers, serve as an air navigation communications hub and as a forward secure base to cope with emergencies.

The major disadvantage of the concept is its high cost which was estimated at approximately \$472 million (Cdn). The study showed a very high variation in the capital estimates and the figure quoted above represents the upper end of the range. For the Hibernia field, the site for which the concept appeared to be most feasible, it would not likely be economic unless the traffic demand in the range of 260,000 to 325,000 one-way persons trips annually would materialize. This represents offshore based employment of approximately 5,000 to 6,000 persons, well above the levels currently forecast.

12.2.2 STOLport Barges

A number of floating STOLport barge concepts have been examined resulting in the development of design which would be cheaper to construct than the semi-submersible STOLport. Three barge concepts were developed, all having approximately the same capability as the semi-submersible concept. These barge concepts included:

- a) a STOLport barge researched by Seaforth Maritime, featuring a specially designed and proportioned hull to give it motion characteristics which compared favorably with the semi-submersible concept. This barge was also capable of providing a crude oil storage capacity 4.5 Million barrels. Its estimated cost was \$374 million (Cdn).
- b) a STOLport barge concept, developed by Albery, Pullerits and Dickson, which would be fabricated from five surplus VLCC's having similar characteristics to the semi-submersible concept. It would cost costing approximately \$250 (Cdn.) million. This vessel could be fabricated at a Canadian drydock at a premium of 20%.

- c) VLCC barges, fabricated as outlined in (b) but capable of providing crude oil storage ranging from 1.75 million to 3.5 million barrels. Costs would be in the order of \$262 million to \$272 million (Cdn) respectively.

The STOLport barge concepts were all judged to be technically feasible and to be capable of safe operation on Canada's east coast. If no benefit was taken for the crude oil storage capability of the vessels, the Seaforth Maritime barge would break even at traffic levels ranging from 210,000 to 260,000 annual person trips and the VLCC barge at levels ranging from 160,000 to 210,000 annual person trips. The minimum breakeven traffic levels represent offshore based employment of approximately 3,000 to 4,000 persons which again are considerably above current forecasts. The VLCC barge estimates are highly sensitive to the availability of suitable surplus VLCC's at a reasonable cost.

If full economic utilization could be made of the available crude storage capacity of the barges, the break even trip levels would range from 90,000 to 137,000 person trips annually. This represents an offshore based employment of approximately 1600 to 2700 persons. The lower of these two estimates approaches the upper levels currently forecast for employment the Hibernia field.

12.2.3 Fixed Heliports

Four heliport concepts were examined; two were gravity base structures for water depths in the order of 100m, and two were for construction on the Virgin Rocks at a water depth of approximately 10m. The artificial island heliports were estimated to cost in the order of \$560 million (Cdn), and the Virgin Rock concepts \$95 million (Cdn). The artificial island concepts require a traffic level of 703,000 person trips annually to break even and the Virgin Rock concepts 152,000 person trips annually. These concepts do not compare favourably with the most economic STOLport barge concepts, nor would they provide as many secondary benefits.

12.2.4 Floating Heliports

Three floating heliport concepts were examined including:

- a) VLCC conversion at a cost of \$41 million (Cdn.)
- b) Semi-submersible structure costing \$100 million (Cdn.).
- c) Tension leg structure costing \$116 million (Cdn.)

These concepts had annual break even traffic levels of 127,000, 148,000, and 184,000 person trips annually respectively. As such, they compared favorably with the VLCC STOLport barge concepts having a crude oil storage capability. For these concepts to be viable in the context of the primary transportation function they would have to provide a more reliable service, with lower delay costs, this is the case with direct helicopter service to the platforms. This might be achieved by a self-propelled heliport coupling directly to a platform or by rising marine vessels of the Swath type to replace the Secondary helicopter shuttle. Such systems would only be practical if Category III operations by helicopter were feasible.

12.3 Secondary Systems Findings

12.3.1 Meteorological Services

The environment off of the east coast of Canada is characteristically harsh and the conditions that prevail at a given time near land based airports and meteorological installations can vary widely from those at offshore destinations. The offshore weather information is therefore viewed as a special purpose requirement for a unique situation; and can best be improved by locating sensing equipment and transmitter installations in proximity to the offshore area of interest. This is especially critical for gathering information on the correlation between visibility, winds and sea states, factors which are becoming

increasingly significant because of the prevalence of IFR Category II and Category III weather. Better data will be required for assuring the viability of future automatic landings (Category IIIa) for both fixed wing and rotary wing aircraft. Equally important, special consideration should be given to the requirement to develop or restructure methods of recording and presenting special purpose aviation weather for offshore facilities planning. It is recommended that consideration be given to the development of data programs which would show correlation between ceiling/horizontal visibility, winds and sea state, upon which estimates of availability of floating heliports or STOLports can be based.

12.3.2 En Route Navigation

There will be a requirement to standardize on a single long range en route navaid system, possibly either LORAN C or OMEGA, supplemented by VOR/DME installations. Consideration should also be given to the installation of offshore peripheral (PAL) communications facilities to ATC centres to improve air traffic control procedures in the vicinity of the platforms.

A representative system might include very High Frequency AM radio at the PAL site for communications with aircraft in the area and a high power High Frequency Single Side Band radio link to the mainland ATC.

Consideration should be given to the improvement en route navigation through the provision of more precise weather briefings, and more formalized ATC/FSS services. Currently, air traffic control and flight planning services are of an "interim" or informal nature, due to the small numbers of aircraft shuttling between rigs and shore bases. In future, as services are expanded, additional control of the offshore airspace will probably be desirable locating of ATC/FSS units, complete with personnel and equipment at the offshore STOLports and heliports, could also be a requirement.

IFR Alternates (Helicopter Operations)

Presently the use of offshore facilities as auxilliary landing sites or IFR alternates is not permitted in Canada to date. It is recommended that consideration be given to permitting this type of practice at licenced, fixed or floating ST Lports or heliports, to allow shuttle operations to continue in marginal weather conditions, as is the practice at shore-based airports or heliports. The resulting advantage would be the maximized use of aircraft in use due to improved payload/range performance.

12.4 Development Implications

12.4.1 Rotary Wing Aircraft Development

The forecast level of helicopter operations off of Canada's east coast does not by itself justify development of new basic helicopter technology in Canada. Indeed, because of the high development costs involved relative to the potential for improvement, new, basic equipment in U.S. and Europe will only be developed as part of military programs. None of the advanced equipment concepts examined appear to offer major scope for radical operational changes or for significantly improving economies from those currently experienced with existing aircraft. There is, however, considerable scope for the improvement of helicopter reliability and safety through the development of special purpose systems in such areas as ice detection, air to ground communications, landing aids and en route nav aids. Canadian industry already has a strong capability in these areas and through further aggressive marketing could increase its market share.

12.4.2 Floating Heliports

The study could not substantiate the economic viability of the new special purpose heliports considered. The alternative of a two stage shuttle, involving transfer of passengers at a offshore heliport from large to smaller helicopters does not offer significant economic benefits because the potential cost savings in the long haul leg are generally more than offset by the capital and operating costs incurred by the floating heliport facilities and the offshore shuttle service necessary to connect to the platform. There is also loss of time involved in the transferring of passengers between the en route and shuttle helicopters.

while not specifically falling within the scope of the study, the possibility of using a floating heliport as a forward service base for providing support services under both normal and emergency conditions was identified. This concept deserves further consideration.

12.4.3 Floating STOLports

Floating STOLport concepts which can also provide crude oil storage could be economic at the upper level of the current traffic forecast for Hibernia depending upon the level of shared benefits assumed for the available storage capability. It is technically feasible to construct such vessels of the necessary size and stability to accommodate highly reliable Dash-7 operations.

The drydocks and supporting infrastructure required to construct the floating STOLports do not exist in Canada, and the construction of a temporary drydock coupled with other costs associated with Canadian construction will increase overall costs by approximately 20% for the

converted VLCC STOLport barge concept. Construction of an all new vessel such as the Seaforth Maritime STOLport barge might be feasible in Canada but it would have to be constructed in modules joined together for completion.

The floating STOLport barge concept is recommended for study by government and industry as it appears to offer considerable scope in reducing transportation costs and for improved reliability, comfort and convenience in the offshore air transportation system. Coupled with this solution, are very significant potential economic benefits to Canada resulting from the manufacture of Dash-7 aircraft to support resource development.

12.4.4 Landing Systems

Category III landings at floating STOLports and heliports appear feasible, however, the limited weather data available to the study did not permit a precise assessment of potential benefits. Given that Category II limits control at Hibernia, air operations could be at a standstill 13% of the time on an annual basis. The Dash-7 does not have the necessary auto pilot and control systems for fully automatic Category III landings, but the potential benefits attainable from operating at reduced limits appear to justify examining the problems involved in upgrading the aircraft in this respect. The undertaking of such an evaluation would be dependent upon a favourable reaction by the oil industry to the prospects for offshore STOLport operations.

Development of systems to permit Category III landings by helicopters is underway but such operations may be precluded at offshore platforms because of intrusion of platform superstructures into the approach airspace.

12.4.5 Special Purpose Marine Vessels

Vessels of the semi-submersible catamaran type could provide a viable substitute to the second stage offshore helicopter shuttle, that would otherwise be required with either floating heliports or STOLports. Based on a system-to-system comparison, excluding the cost of weather-related delays, the break-even traffic level between semi-submersible vessel relative to helicopter operations is approximately 100,000 person trips annually.

While it was outside the scope of this study to examine marine transport problems, the semi-submersible hull vessels appear to offer significant advantages over conventional vessels for operating in heavy seas. Their surge/heave characteristics can closely match those of semi-submersible platforms thereby facilitating passenger transfer during high sea states. The effects of ice build-up require further research in the context of the Canadian east coast environment. There may also be opportunities for manufacturing of or producing components for such vessels in Canada. This aspect was not examined.

12.4.6 Offshore Fixed Airports and Heliports

The cost of developing the Virgin Rocks site as an offshore heliport does not appear to be economically justifiable. If the site was developed for other uses, the inclusion of heliport facilities would provide benefits to the offshore aviation industry particularly if the heliport could be designated as an IFR alternate.

The development of a STOLport at Sable Island could result in significant operating benefits to offshore aviation and resource industries. It could be the most cost-effective offshore STOLport/heliport solution for the Venture field and, therefore, its feasibility in both economic and environmental terms should be established.

12.4.7 Facilities and Infrastructure

Requirements for centralized government operated facilities in the areas of communication, en route navigation, law enforcement, safety services, general administration and control will increase as the level of offshore activities grow. Such requirements individually will not significantly effect the economics of any of the concepts researched in this project, however, the opportunities for providing such facilities in larger centralized structures where costs might be shared with the oil industry should be considered on an on-going basis.

12.4.8 Floatel Facilities

The North Sea experience indicates a continuing requirement for offshore work platforms housing up to 500 workers for the construction of production platforms. Such requirements have not been identified for Canada's east coast. Should such facilities prove to be necessary, combining them with a floating STOLport could tip the economic balance in favour of fixed wing aircraft operations. The requirements for floatel facilities should be monitored by industry and government, and should the current view change, the viability of the semi-submersible STOLport concept should be reassessed.

12.5 Major Conclusions and Recommendations

Canada's east coast offshore petroleum resource recovery operations can be considered to be in their infancy and therefore the scale of future production cannot be precisely established for the longer term. All of the floating STOLport concepts examined in this study could be economically justified at employment levels approximately 2.5 times those con-

tained in the current maximum forecast. The floating STOLport barge concepts are marginally uneconomic for the Hibernia field at the upper employment level forecasts. If the crude oil storage capability of the barge concepts could be effectively utilized, these concepts could be economic at below the upper forecast employment level. This is an area for further consultation with the oil industry. Monitoring the need to carry out more detailed studies on this concept is the major recommendation of this study.

New special purpose floating heliports, while offering the potential for improved service reliability cannot be justified on economic grounds. However, conversion of existing offshore floating structures for use as IFR alternate heliports appears feasible and potentially attractive as a relatively low-cost means of providing a forward base to support a variety of industries/government agencies. The Government should consider examining the operating implications, design requirements and standards for such facilities in order to be in a position to provide advice and support to the offshore aviation and oil industries as this is beyond the scope of the study conducted.

The format of the offshore weather data bank does not readily lend itself to aviation weather analysis to the required level of detail. Consideration should be given to expanding the capability of AES in the gathering of data in more directly applicable formats and with the necessary correlation between air and sea state conditions. These requirements should be addressed on a priority basis.

Air traffic in support of east coast energy resource recovery will increase more rapidly than will scheduled and general aviation traffic particularly if helicopters remain the only air mode. This will increase the pressure on the Government to provide levels of air traffic control service and telecommunications facilities more in keeping with its onshore standards and responsibilities.

A number of potential areas for Canada's involvement in the production of air transportation facilities and equipment for offshore operations were identified. These include:

- o Avionics and ice detection systems for helicopters
- o Special purpose navigation and communications systems
- o Floating STOLport components of the floating barge type
- o STOL aircraft design and manufacture.

The potential for exporting the technology resulting from transportation equipment would be greatest in the areas of avionics, aircraft, offshore communications and nav aids equipment. The Hibernia area offers a good testing ground for equipment both because of its remoteness from land and because of the harsh marine and weather operating environment.

Implementation of the STOLport concept would increase the opportunities for the export of Dash-7 aircraft, but exports of floating STOLports does not appear to be likely primarily because of high Canadian ship building costs.

The tilt rotor/wing aircraft, is technically exciting, and if further developed and certified for civilian use it could play a role in offshore transportation in the longer term.

Although outside the scope of this study, the catamaran semi-submersible marine vessel appears to have good motion/reliability characteristics, and warrants further study, both in terms of its utilization for east coast transportation and as a possible product for Canadian manufacture.

Bibliography

BIBLIOGRAPHY

- | | |
|---|---|
| Blenkarn, K.A. and Knapp, A.E. | <u>Ice Conditions on the Grand Banks</u> , CIM Special Volume 10, The Ice Seminar. 1969. |
| Condos Marine Consultants Limited | <u>Conceptual Study into the Role of the Swath Ship for Offshore Duties</u> , Cumbria U.K. 1981. |
| Department of Industry, Trade and Commerce | <u>Hibernia: Supply/Demand Study</u> , Ottawa, September, 1981. |
| Gustajtis, K.A. | <u>Iceberg Population Distribution Study in the Labrador Sea</u> . Technical Report, C-Core, August 1978. |
| Haviland, J.K. | <u>A Preliminary Study of Container Concepts for Aircraft Landing on Elevated STOLports</u> . Report No. AEEP 4068-101-71U Division of Aerospace Engineering and Engineering Physics. Research Laboratories for the Engineering Sciences, University of Virginia, Charlottesville, October, 1971. |
| Hydronamic | <u>Engineering for Man-made Islands in the Arctic</u> . Slidrecht, Holland |
| International Labor Office. | <u>Yearbook of Labor Statistics</u> , Geneva, 1981. |
| Imperial Oil Ltd. and Albery, Pullerits, Dickson and Associates Limited | <u>Design and Construction of A Caisson Retained Island Drilling Platform for the Beaufort Sea</u> . Offshore Technology Conference, 1978. |
| Lewis J.K. and Benedict C.P. | <u>Burial Parameters: An Integrated Approach to Limit Overdesign</u> . Proceedings of the Symposium on Production and Transport Systems for the Hibernia Discovery. St. John's Newfoundland, February 16-18, 1981. |
| Lucero, F.N. | <u>The Arresting Cable Pop-Up Device</u> . AFFTC-TR-61-17 United States Air Force - Edwards Airforce Base, April 1961. |
| McGraw-Hill | <u>Aviation Week & Space Technology</u> . Vol. 118, No. 23, New York, June 6, 1983. |
| McIntyre, N.F. | <u>The Ability of Floating Platforms and Tankers to Operate in the Hibernia Environment</u> . Mobil Oil Canada Ltd. |

- McIntyre N.F., Environmental Forces on a Fixed Platform and the Ability of the Platform to Resist Them. Proceedings of the Symposium on Production and Transportation Systems for the Hibernia Discovery. Mobil Oil, Canada Ltd. St. John's Newfoundland. February 16-18, 1981.
- McLean-Hunter Oilweek, Vol. 34, No. 16, Calgary, May 23/83.
- Markham W.E. Ice Atlas-Eastern Canadian Seaboard Atmospheric Environment Services Publication E-56-55/1981.
- Mitsui Engineering Mitsui Semi-Submerged Catamaran (SSC) for Offshore Personnel Transport, MI-82201 Tokyo, April 1982.
- Mobil Oil Canada Ltd. Venture Development Project Environmental Impact Statement Vol. 1 to 4. Mobil Oil Canada Ltd., Halifax, February 1983.
- Neu, H.J.A. 11-Year Deep Water Wave Climate of Canadian Atlantic Waters, Canadian Technical Report of Hydrography and Ocean Sciences No. 13. October 1982.
- Rotor & Wing International. June 6, 1983.
- Schwarz, U. ICAO Bulletin, Vol. 38, No. 5, Montreal May, 1983.
- Seaforth Maritime Ltd. Seaforth Stolport, An Alternative Transportation Concept. Seaforth Maritime Limited, Aberdeen, March, 1981.
- Sorensen, B.M., et al STOLport An Alternative Offshore Transport System OR22121281.18.01. The Ship Institute of Norway, Marine Technology Center, Trondheim, December, 1981.
- Taylor, J. W. (Ed.) Jane's All the World Aircraft 1982-83, London.
- The deHavilland Aircraft of Canada Limited Dash 7 Flight Manual PSM 1.71 A-1A, Downsview, February 1979.

- | | |
|---|---|
| The de Havilland Aircraft Company of Canada Limited and Seaforth Maritime Limited | <u>Dash 7 - Seaforth STOLport for Offshore Transportation</u> Downsview, 1982. |
| Thomason, T. | <u>ICAO Bulletin Vol. 38 No. 8.</u> Montreal, August 1983. |
| Transport Canada | <u>Airport Related Accidents-Landings.</u> CPS76-5 Transport Canada, Ottawa, 1976. |
| Transport Canada | <u>A Survey of Airplane Arrestment Techniques,</u> CPS-76-1, Transport Canada, Ottawa, 1976. |
| Transport Canada | <u>Civil Aviation Weather Plan Ontario Region</u> OCAP 8250 Transport Canada Civil Aviation Branch, Civil Aviation Planning Division, Ottawa, November, 1982. |
| U.S. Department of Commerce | Bureau of Labor Statistics, February 1981. Unpublished Statistics. |
| Voyer, Roger | <u>Offshore Oil Opportunities for Industrial Development and Job Creation.</u> Canadian Institute for Economic Policy. Ottawa, 1983. |
| Zagarella, A. et al | <u>Arresting Gear Tests for Elevated Short Take-Off and Landing Ports (STOL)</u> Department of Defense Lakehurst, November, 1972. |

**APPENDIX A
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APPENDIX B
LIST OF INTERVIEWEES

The following individuals were interviewed for the purposes of this project work. Those designated with an asterisk * provided follow up commentary.

<u>NAME</u>	<u>SUBJECT OF INTERVIEW</u>
<u>A. Transport Canada</u>	
F. Black, Ottawa, Ont.	Helicopter IFR and contacts in Transport Canada
R. Jingles, Moncton, N.B.	IFR enroute procedures and air traffic control in offshore areas
G. Patterson, Moncton, N.B.	Helicopter operations to oil rigs
W. McKenzie, Moncton, N.B.	Offshore navigation procedures
A. Hayes, St. John's, Nfld.	Helicopter operations to Newfoundland offshore area
J. Hastie, Ottawa, Ont.	MLS applications to improve helicopter precision approach capabilities
R. Sierolawski, Ottawa, Ont.	Heliport and helideck design standards
C. Toronto, Ottawa, Ont.	Aircraft systems upgrading for Category III IFR operations
J. Bray, Ottawa, Ont.	Helicopter flight safety
W. Statham, Toronto, Ontario	Marine NavAids
*L. Swanston, Ottawa	Visibility information for land based sites.
<u>B. Atmospheric Environment Service</u>	
D. Gullett, Toronto, Ont.	Aviation weather at selected east-coast Canadian points
M. Webb, Toronto, Ont.	Possible proxies for helicopter airframe and rotor icing
*A. Gates, Ottawa, Ont.	Aviation weather at selected sites.

*D. Mudry, Ottawa, Ont.

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Helicopters, St. John's,
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Capt. V. Alberts, Petroleum
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D. Helicopter Manufacturers

E. Sanders, Sikorsky
Aircraft, Stratford, CT

J. Reilly, Sikorsky
Aircraft, Stratford, CT

W. Drury, Sikorsky Aircraft,
Stratford, CT

J. Graham, Sikorsky
Aircraft, Vancouver, B.C.

Sea Ice conditions for selected
areas.

Helicopter operating costs

Offshore helicopter operating
procedures

Helicopter operations to Hibernia
area

Offshore helicopter operations
and costs

Offshore helicopter operating
procedures

Helicopter operating costs

Air operations to Sable Island

IRF helicopter operations in
U.S. Gulf coast

Sikorsky helicopter specifica-
tions, mainly S-61N

Sikorsky UH-60 Black Hawk de-
icing

S-61N operating costs

Sikorsky helicopter specifica-
tions, mainly S-76

J. Madden, Bell Helicopter
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Company, Philadelphia, PA

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*W.C. Sloan, Bell Boeing
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Helicopter Corporation,
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S. Moss, Vantage
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Government Avionics
Division, Rockwell
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Cedar Rapids, IA

Bell 214ST specifications

Boeing 234LR specifications

AS332L Super Puma specifications

Tilt Wing Aircraft JVX Program

Aerospatiale helicopter specifi-
cations

Specifications and costs for
Agusta AS-61N1 and EH-101

MLS, precision DME and Category
III operations for helicopters

MLS and precision DME and Cate-
gory III operations for helicop-
ters, VOR/DME for offshore navi-
gation aids

Ice detection systems for heli-
copters

Ice detection systems for
helicopters

Helicopter flight control systems
for precision IFR

F. Miscellaneous

E. Lane, Lane Brack,
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Helicopter Insurance rates

Offshore helicopter operations

Worker turnaround policy and
delay costs on oil rigs

Dash-7 operating costs

Artificial island development

Logistics

Logistics

APPENDIX C

Glossary of Terms

Avionics	Aircraft instrumentation
ASD	(Accelerate Stop Distance) - The accelerate stop distance is the sum of the following: - The distance required to accelerate the aircraft from a standing start to the speed V_1. - Assuming a critical engine failure at V_1, the distance required to bring the engine to a full stop from the point at which V_1 speed is attained.
Balanced Field Length	This holds when the take-off distance equals or exceeds the accelerate stop distance.
Clearway	The area beyond the edge of the take-off surface, being a width of 500 ft or 152 m. minimum, centred on the extended centreline of the take-off runway under the control of the airport authority. The clearway plane extends from the end of the runway at an upward slope not exceeding 2.5%, above which no object or terrain protrudes.
CAA	Civil Aviation Administration (Britain)

F.A.A.	Federal Aviation Administration
F.A.R.	Federal Aviation Regulation
IFR	Instrument Flight Rules
ICAO	International Civil Aviation Organization
ISA	International Standard Atmosphere
ILS	Instrument Landing System
IDU	Helicopter de-icing equipment, Ice Detection Unit
IRU	Helicopter de-icing equipment, Integrating Rate Unit
Loran A/Loran C	Navigation systems utilized to obtain exact co-ordinates for vessel tracking
MLS	Microwave Landing System
RNAV	Area navigation
RTOL	Reduced take off and landing
RVR	Runway Visual Range
Stillair	Atmospheric State of Calm
STOL	Short take off and landing
TACAN	Tactical Air Navigation Equipment (UHF Omni Range)
TOD	(Take-Off Distance) - The take-off distance is the longer of the following: a. The distance from the start of the take-off roll to the point where the aircraft attains a height of 35 ft. (10.6 m.) above the take-off surface, with critical engine failure at V.

b. 115 percent of the distance from the start of take-off roll to the point at which the aircraft attains a height of 35 ft. above the take-off surface with all engines operating normally.

V1

(Critical engine failure recognition speed) - Speed at which, due to engine failure or other causes, the pilot may elect either to stop the aircraft or to continue take-off.

V2

(Take-Off Safety Speed) - The climb speed to be attained at or before a height of 35 feet above the take-off surface during a continued take-off following an engine failure.

V35

Take-off speed to be attained at or before a height of 35 feet above the take-off surface during a continued take-off with all engines operating normally.

Vertical Closing Velocity

Speed at which an aircraft approaches a landing/touchdown point

VFR

Visual Flight Rules

VLCC

Very Large Crude Carrier (Supertanker)

VOR/DME

Very High Frequency Omni-Directional Range Distance Measuring Equipment

VORTAC

Combination of VOR and TACAN

VR

(Rotation Speed) - Speed at which aircraft rotation is initiated during take-off to attain the required V2 climb speed at or before a height of 35 ft. above the take-off surface.

VTM

(Vessel Traffic Management Centres)
Radar tracking centres operated by
Transport Canada Assisting in the
control of marine traffic utilizing
established shipping routes